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THESIS

AN ANALYSIS OF THREE APPROACHES TO THE HELICOPTER PRELIMINARY DESIGN PROBLEM

by

Allen C. Hansen

March 1984

Thesis Advisor: D. M. Layton

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Three methodologies from which to approach the problem of preliminary helicopter design are explored in this paper. The first is a sensitivity analysis of the basic helicopter performance equations. The purpose here is to ascertain where reasonable simplifications can be made that do not seriously degrade the accuracy of the results. The second is a graphical parametric design method, known as Carpet Plots. In this method

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a graphical solution is developed to meet the design criteria of the helicopter. In the third, an overview of Boeing Vertol's Helicopter Sizing and Performance Computer Program is given. The computer routines which enable a person to access HESCOMP on the Naval Postgraduate School main frame IBM system are also provided.

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An Analysis of Three Approaches to the Helicopter Preliminary Design Problem

by

Allen C. Hansen
Lieutenant, United States Navy
B.A., University of Pennsylvania, 1976

Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

Three methodologies from which to approach the problem of preliminary helicopter design are explored in this paper. The first is a sensitivity analysis of the basic helicopter performance equations. The purpose here is to ascertain where reasonable simplifications can be made that do not seriously degrade the accuracy of the results. The second is a graphical parametric design method, known as Carpet Plots. In this method a graphical solution is developed to meet the design criteria of the helicopter. In the third, an overview of Boeing Vertol's Helicopter Sizing and Performance Computer Program is given. The computer routines which enable a person to access HESCOMP on the Naval Postgraduate School main frame IBM system are also provided.

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I. INTRODUCTION

A. GENERAL

The helicopter design process, the subject of numerous articles and studies is an evolving discipline that borders on being an art. A successful design must balance the user's needs and desires against practical capabilities.

With the introduction of composite materials and new technologies, principally in rotor and engine performance, significant advances have been made in helicopter capabilities. In some instances, the performances of hybrid helicopter designs rivals that of a similarly sized conventional aircraft. For example, the YVX, a joint Boeing-Bell venture, will have the hover and low speed capabilities of a helicopter while being able to cruise at 300 knots.

Viable commercial and military helicopter designs are only thirty years old. The first major use of helicopters occurred during the Korean conflict. To put this in perspective, the first large scale use of conventional type aircraft was in World War I.

Helicopter design can proceed on a number of different levels, ranging from comprehensive computer design programs to preliminary analysis using simplifications of the basic performance equations. Each has its merit and place. Computer-aided design provides a great deal of data.

Generally, these programs integrate aircraft configuration sizing, performance and weight calculations in an iterative process. An example of a computer design program for helicopters is the Helicopter Sizing and Performance Computer Program [HESCOMP], orginally developed by Boeing-Vertol for NASA. This program is currently used as a wide number of institutions conducting studies in helicopter design.

On the opposite end of the spectrum would be sensitivity design studies using the performance equations. Surprisingly accurate simplications of these equations can be made. This provides the designer with an excellent method for doing first cut preliminary helicopter sizing at a low cost.

B. OBJECTIVE

This report is an investigation of several of the methods employed in the preliminary design of a helicopter. Conceptually, the report can be divided into three parts. In the first section, a sensitivity analysis of the basic performance equations is performed. The purpose here is to ascertain where reasonable simplications can be made that do not seriously degrade the accuracy of the result.

In the second section a graphical method of doing parametric design studies, known as Carpet Plots, is developed. This method allows the user to formulate a graphical solution matrix to meet the design criteria specified for the helicopter. Carpet Plots are

particularly instructive since they give visual insight into the interplay of the various design parameters.

In the last section, an overview of HESCOMP is given. Programs are developed which enable a person to access HESCOMP on the Naval Postgraduate School Main Frame IBM system.

II. SENSITIVITY ANALYSES OF BASIC HELICOPTER EQUATIONS

A. DESCRIPTION OF PROBLEM

In preliminary helicopter design, there are a number of instances where a quick first cut analysis would be extremely helpful. This is especially true in determining the preliminary size of the helicopter required to meet the specifications.

Historically, there are a number of variables in the performance equations of helicopters which may be treated as constants. This may allow for significant simplifications and aid in the preliminary design process.

In this section, a sensitivity analysis of the performance equations is done. In a sensitivity analysis, each parameter [or variable] is varied in order to determine its effect on the equation. Variables which are shown to have little effect may be treated as constants and the equation simplified accordingly.

B. SOLIDITY

Solidity, σ , is the fraction of the disk area that is composed of blades. It is a function of b , the number of blades, of a constant cord, c , at a radius, R:

$$\sigma = \frac{bc}{\pi R} \tag{2.1}$$

C. DISK LOADING:

Disk loading is defined as the ratio of the weight to the total area of the rotor disk.

$$DL = \frac{\text{WEIGHT}}{\text{AREA}} \qquad (2.2)$$

$$= \frac{W}{A} = \frac{W}{\pi R^2} \; [\text{lb/ft}^2]$$

D. POWER LOADING

Power loading is the ratio of weight to input power.

$$PL = \frac{W}{P_{in}} \; [\text{lb/hp}] \qquad (2.3)$$

In a hover, thrust equals weight; this allows us to rewrite the power loading for the hover condition as

$$PL = \frac{T}{P_{in}} = \frac{\text{ROTOR THRUST}}{\text{ROTOR HORSEPOWER}} \; [\text{lb/hp}] \qquad (2.4)$$

E. COEFFICIENT OF THRUST AND POWER

The coefficient of thrust, C_T , is a non-dimensional coefficient which facilitates computations and comparisons:

$$C_T = \frac{T}{A\rho V_T{}^2} = \frac{T}{\pi R^2 \rho (\Omega R)^2} \qquad (2.5)$$

Similarly, a coefficient of power, C_p , has been established as:

$$C_p = \frac{P}{A\rho V_T{}^3} = \frac{P}{\pi R^2 \rho (\Omega R)^3} \qquad (2.6)$$

No significant simplifications can be made to either of these coefficients. However, it should be observed that the coefficient of thrust is inversely proportional to the square of the rotor tip velocity, while the coefficient of power is inversely proportional to the cube.

Assuming all other factors being equal, increasing the rotor tip velocity from 600 fps to 700 fps [an increase of 16.7 percent] will have the following result on these coefficients.

$$C_T = \frac{T}{A\rho V_T{}^2}$$

$$= \frac{T}{A\rho (1.167)^2} \qquad (2.5)$$

$$= \frac{T}{A\rho (1.361)}$$

The coefficient of thrust is reduced by 26.9 percent.

Similarly, for the coefficient of power:

$$C_P = \frac{P}{A\rho {V_T}^3}$$

$$= \frac{P}{A\rho (1.167)^3} \qquad (2.6)$$

$$= \frac{P}{A\rho (1.589)}$$

The coefficient of power is reduced by 37.1 percent.

F. HOVER POWER

The total power in a hover is made up of two terms, profile power, P_o , and induced power, P_i .

Utilizing black element theory the profile power required to hover can be expressed as:

$$P_o = \frac{1}{8} \sigma_r \bar{C}_{do} \rho A(\Omega R)^3 \qquad (2.7)$$

The induced power predicted by momentum theory is:

$$P_i = V_{in} T \qquad (2.8)$$

$$= \frac{T^{3/2}}{\sqrt{2\pi \rho R^2}}$$

The total power required to hover is:

$$P_T = P_i + P_o \qquad (2.9)$$

$$P_T = \frac{T^{3/2}}{\sqrt{2\pi\rho R^2}} + \frac{1}{8}\sigma_r \overline{C}_{do}\, \rho\, A(\Omega R)^3 \qquad (2.10)$$

Donald M. Layton in Helicopter Performance, [Ref. 1], found that for the optimum hover power, the induced power is equal to twice the profile power. The analysis was performed in the following manner.

By assuming constant weight, density, solidity, and an average profile drag coefficient, as well as a fixed rotational velocity, equation (2.10) reduces to

$$P = \frac{C_1}{R} + C_2 R^2 \qquad (2.11)$$

where C_1 and C_2 are constants.

As equation (2.12) shows, profile power increases as the square of the blade radius while the induced power decreases with increasing blade radius.

The optimum hover power with respect to rotor radius can be determined by taking the differential and setting it equal to zero.

$$\frac{dP}{dR} = 0 = -\frac{C_1}{R_2} + 2\ C_2 R \qquad (2.12A)$$

or

$$\frac{C_1}{R} = 2\ C_2 R^2 \qquad (2.12B)$$

which implies

$$P_i = 2\ P_o \qquad (2.12C)$$

G. HELICOPTER SIZING

A simplified relationship between the total power required, gross weight and rotor radius can be developed in the following manner.

The total power required to hover equation for the main rotor was developed in the preceding section and is repeated here for clarity.

$$P_T = P_i + P_o \tag{2.9}$$

$$P_T = \frac{T^{3/2}}{\sqrt{2\pi\rho}} \cdot \frac{1}{R} + \frac{1}{8}\,\sigma_r\,\overline{C}_{do}\,\rho\pi\,V_{tip}^{\;3}\,R^2 \tag{2.10}$$

In a hover, thrust equals weight. Solving equation (2.11) for weight one obtains:

$$W^{3/2} = [P_T - \frac{1}{8}\,\sigma\,C_{do}\,\rho\pi\,V_T^{\;3}\,R^2]\,\sqrt{\rho A} \tag{2.13}$$

This equation may be further simplified if it is assumed that the density, average profile drag coefficient and tip velocity are constants; these are reasonable assumptions. Historically, the average profile drag coefficient of a helicopter has been approximately 0.01. The operating environment of today's helicopters, especially military, is below 5,000 feet agl. This allows for the use of the standard sea level value for density with little error. Primarily, due to tip mach effects, the upper limit on the rotor tip velocity is in the range of 700 fps.

The resulting equation with these assumptions incorporated into a constant, K , is:

$$W = [47.527\ P_T\ R - K_1\ bc]^{2/3} \qquad (2.13)$$

Equation (2.13) can be further reduced when the order of magnitude of the two terms is considered.

$$47.527\ P_T\ R >> K_1\ bc$$

Thus,

$$W \approx [47.527\ P_T\ R]^{2/3} \qquad (2.14)$$

To determine how accurate this simplification is, the equation is used to approximate the total weight of a number of helicopters for which the parameters are available. As Table 2.1 indicates, the weight approximation formula yields values within six percent of the actual total weight of these helicopters.

H. FIGURE OF MERIT

A figure of merit, FM , has been defined for the helicopter as the ratio of the ideal rotor induced power to the actual power required to hover, with non-uniform induced velocity, tip losses and profile drag power.

TABLE 2.1

HELICOPTER WEIGHT COMPARISON

HELICOPTER	TOTAL GROSS WEIGHT (1000 lbs)	CALCULATED GROSS WEIGHT (1000 lbs)	PERCENT OF ACTUAL GROSS WEIGHT
AH-64	14.66	14.69	101%
UH-1N	14.20	13.74	97%
H-3H	21.00	20.63	98%
S76	10.00	9.90	99%
UH-60A	20.25	19.33	95%
H-54B	42.00	42.00	100%
H-53D	42.00	41.00	98%
H-53E	73.50	69.00	84%

In a hover, the figure of merit may be written as:

$$FM = \frac{1}{\sqrt{2}} \cdot PL \cdot \frac{DL}{\sqrt{\rho}} = \frac{CT^{1.5}}{\sqrt{2C_p}} \qquad (2.15)$$

The figure of merit is customarilty plotted against the quantity CT/σ . According to Zalesch [Ref. 2], CT/σ , is proportional to the average blade angle of attack and can be used as a measure of rotor efficiency. The curve in Figure 2.1 is based on data from Reference 2 for a typical tail rotor helicopter.

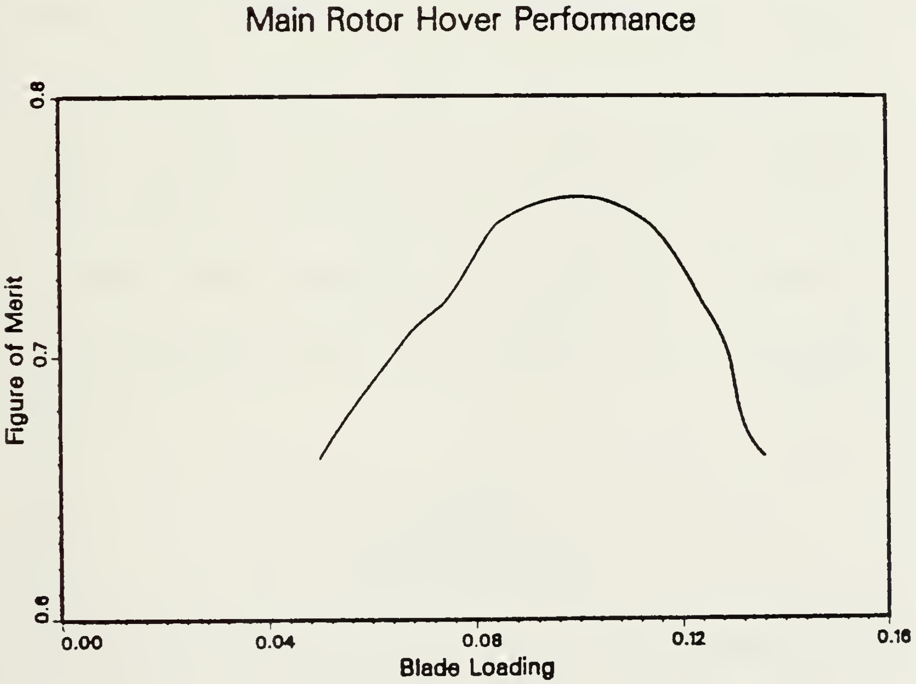

Figure 2.1. FM Versus Blade Loading CT/σ

Previous studies have shown that a figure of merit between 0.70 and 0.80 is considered average.[Ref. 3] If the induced power is between 70 and 80 percent of the total power, the figure of merit will be approximately 0.75.

With the figure of merit limited to values between 0.70 and 0.80, the following simplification can be made, assuming the hover condition of thrust equaling weight and standard sea level conditions:

$$FM = \frac{W^{3/2}}{67.214\ P_T R} \qquad (2.16)$$

For Navy helicopter design, the rotor radius has been limited by flight deck spotting constraints to less than 30 feet; the exception to this is the H-3, R = 31 feet and the H-53, R = 36 to 38 feet [depending on the model]. However, these two helicopters work almost exclusively from large air dedicated ships such as the LPH, LHA and CV.

If the small deck operating assumption is made, equation (2.16) can be further simplified to [assuming R = 28 feet]:

$$P = \frac{W^{3/2}}{1881.98\ FM} \qquad (2.17)$$

An FM of 0.80 will yield a P to W relationship of:

$$P_T = \frac{W^{3/2}}{1505.58} \qquad (2.18)$$

while an M of 0.70 yields a relationship

$$P = \frac{W^{3/2}}{1317.39} \tag{2.19}$$

If equation (2.17) is solved utilizing the approximate weight relationship developed earlier of

$$W^{3/2} = 47.527\ P_T R \tag{2.14}$$

a value for the figure of merit of 0.707 is obtained. This is within the historical range of values.

I. TAIL ROTOR SIZING

A historical analysis of typical helicopters [Ref. 3), shows the following empirical relationship for the tail rotor radius

$$R_T \simeq 1.3\ [\frac{GW}{1000}]^{1/2}\ [ft] \tag{2.20}$$

when comparing the results of this equation with actual tail rotor radius data, it was found that if a multiplication factor of 1.2 is used vice 1.3 a better approximation is obtained. The results are tabulated in Table 2.2.

J. FORWARD FLIGHT POWER CONSIDERATIONS

The total power in forward flight consists of induced, profile and parasite power. If the helicopter is a single rotor vehicle, the tail rotor power should be taken into

TABLE 2.2

TAIL ROTOR SIZING

HELICOPTER	ACTUAL TAIL ROTOR RADIUS [FT]	APPROXIMATION [FT]	
		[2.20]	[2.21]
AH-64	4.6	4.98	4.59
UH-1N	4.3	4.90	4.52
SH-3H	5.3	5.95	5.5
S-76	4.0	4.11	3.79
UH-60A	5.5	5.85	5.4
CH-53D	8.0	8.42	7.78
CH-53E	10.0	11.15	10.29

account, as well as all mechanical losses [transmission, etc.] for accurate calculations. However, a reasonable approximation can be obtained by considering only the main rotor and increasing this power figure by several percent to account for these losses.

Figure 2.2 is a plot of the induced, profile, parasite and total power curves for typical tail rotor helicopter.

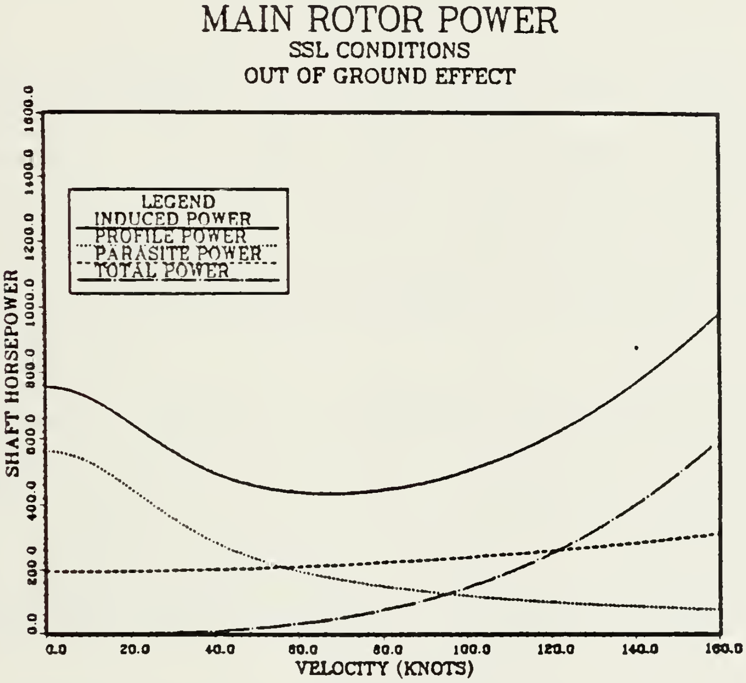

Figure 2.2. Power Required Versus Forward Velocity

The induced power drops off rapidly with increasing forward-velocity, whereas the parasite power increases rapidly.

Parasite power is the power required to overcome the drag forces created by the aircraft's geometry. These drag forces are due to pressure drag and skin friction.

Parasite drag is extremely sensitive to the helicopter's loading. It is generally a minimum for forward flight and increases for sideways flight. Helicopters are generally streamlined for forward flight and the flat plate area is a minimum in this direction. The equation for the parasite power is:

$$P_p = \frac{1}{2} \rho V_f^3 f_f \qquad (2.21)$$

The parasite power is a function of the cube of the forward velocity. As such, with the advent of high speed helicopters a great deal of consideration has been placed on streamlining the geometric shape in order to reduce this power requirement.

Blade element theory is commonly used to develop the profile power equation for forward flight. An excellent development of this equation is given in Reference 1.

The profile power equation in forward flight is:

$$P_{of} = \frac{1}{8} \sigma C_{do} \rho A V_T^3 [1 + 4.3 \mu^2] \qquad (2.22)$$

Equation (2.23) is a function primarily of the main rotor geometry. The variable with the most significance is the rotor tip velocity; increasing the tip velocity from 600 to 700 fps results in a 58.8 percent increase in profile power [assuming other factors are constant].

The induced power is a function of the induced velocity. In a hover, the total flow through the rotor system is induced. As the forward velocity increases, the mass flow rate through the rotor disc increases due to the forward translation of the helicopter. This reduces the induced velocity.

The equation for the induced power requirements at all forward velocities is:

$$P = T \cdot V_{it} \tag{2.23}$$

where

$$V_{it} = \left\{ - \frac{V_f^{2}/V^{2}}{2} + \sqrt{\left[V_f^{2}/2V^{2}\right]^{2} + 1} \right\}^{1/2} .V \tag{2.23a}$$

At high forward velocities, the induced power required can be approximated as:

$$P_i = WV_{it} = \frac{W^2}{2\rho A V_f} \tag{2.24}$$

The total power for forward flight is the sum of the induced, profile and parasite powers.

$$P_T = P_i + P_o + P_p \tag{2.25}$$

$$P_T = T.V_{it} + \frac{1}{8} \sigma C_{do} \rho A V_T^3 [1 + 4.3 \mu^2] + \frac{1}{2} \rho f_f V_f^3 \qquad (2.25a)$$

At high forward velocities, equation (2.23) can be substituted into equation (2.25), resulting in:

$$P_T = \frac{W^2}{2 \rho A V_f} + \frac{1}{8} \sigma C_{do} \rho A V_T^3 [1 + 4.3 \frac{V_f}{\Omega R}] + \frac{1}{2} \rho f_f V_f^3 \qquad (2.26)$$

If one makes the following assumptions:

W = const $\quad C_{do}$ = const

ρ = const $\quad \sigma$ = const

VT = const

Equation (2.26) reduces to

$$P_T = \frac{K_1}{R^2} + K^2 R^2 + P_p \qquad (2.27)$$

The derivative of equation (2.27) with respect to radius is:

$$\frac{dP_T}{dR} = - \frac{2K_1}{R^3} + 2 K_2 R \qquad (2.28)$$

Setting this equal to zero, one obtains:

$$-\frac{2K_1}{R^3} + 2\ K_2\ R = 0 \tag{2.28a}$$

$$\frac{R}{2} * [-\frac{2K_1}{R^3} + 2\ K_2\ R] = 0 \tag{2.28b}$$

$$\frac{K_1}{R^2} = K_2\ R^2 \tag{2.28c}$$

$$P_i = P_o \tag{2.28d}$$

This defines point of minimum total power required for VMAX range. This corroborates with the results obtained by Waldo Carmona [Ref. 4].

If the total power required is differentiated with respect to forward velocity and is set equal to zero, it can be seen that

$$P_i = 3\ P_o \tag{2.29}$$

or

$$\frac{W^2}{2\rho AV_f} = \frac{3\rho fV_f{}^2}{2} \tag{2.30}$$

Solving this equation for velocity results in:

$$V_f = \left[\left(\frac{W}{A}\ \frac{A}{3f_f}\right)^{1/2}\right]^{1/2} \quad \text{ft/sec} \qquad (2.31)$$

According to Carmona [Ref. 4], this corresponds to the best endurance velocity.

K. DENSITY EFFECTS ON TOTAL POWER

The effect of density on the total power required in forward flight is as follows:

The general operating altitudes of a helicopter are below 10,000 feet. The corresponding ICAO STANDARD ATMOSPHERE range for density is

$$\rho = 0.0023769 \ [\text{lb sec}^2/\text{ft}^4] \quad \text{SSL}$$

$$\rho = 0.0017553 \ [\text{lb sec}^2/\text{ft}^4] \quad \text{at 10,000 feet}$$

$\rho/\rho SSL$ varies from 1 to .7385.

The effect on the components of P_T are as follows:

Induced Power:

$$1/\rho/\rho SSL \Rightarrow 1 \text{ to } \frac{1}{.7385}$$

This translates to a 35 percent increase in the induced power.

Parasite and Profile Power:

Both parasite and profile powers are directly proportional to the density ratio. Therefore, as you go up in altitude both P_o and P_p are reduced.

III. CARPET PLOT DESIGN STUDY

A. DESCRIPTION OF PROBLEM

Preliminary helicopter design involves one with a wide range of choices. For any given payload and performance specifications, there a number of helicopter designs that satisfy the requirements. The problem in the preliminary design process is narrowing these possibilities and selecting the design which will provide the best helicopter for the mission.

Obviously, the operating environmental constraints help to define the basic configuration. These constraints are usually specified in the Request for Proposal [RFP], in the case of a military helicopter. For example, typical constraints placed on the design of a Navy helicopter are the size of the ship deck and hangar from which it will be operating, the requirement for a blade fold system, dual engine configuration and IFR capability.

Even with these design constraints, there is still a great deal of leeway. In order to insure that the best helicopter design is selected, an appropriate number of solutions satisfying the specifications should be investigated. Since each solution is generally characterized by a different combination of design parameters, the

selection, according to Greenfield [Ref. 5], can best be made through a parametric study which allows for the optimization of many design parameters.

One method of parametric analysis used is Carpet Plots. This method is based on the simultaneous graphical solution of the weight and hover performance equations. To this solution set is added to the environmental constraints to the helicopters size. This effectively brackets the area of acceptable design solutions.

This method assumes that minimum gross weight is the criterion by which the best [or optimum] design parameters are selected.

B. ASSUMPTIONS

1. Airfoil used is a derivative of the NACA 0012 with the following mean approximate values from Reference 5.

a = slope of airfoil section lift curve, $dC_t/d\alpha$, per rad.

$a = 5.73$

δ = blade section drag coefficient

$\delta_0 = .009$

$\delta_2 = .3$

2. a) The tail rotor radius is assumed to be .16 times the main rotor radius [Ref. 5].

b) The distance between the rotors, or tail rotor moment arm, ℓ_{TR} is 1.19R [Ref. 5]. These ratios reflect the values of maximum rotor diameter and overall length specified as size limitations.

3. B = .97. Historical approximation [Ref. 7].

C. METHODOLOGY

In order to properly develop the weight and performance equations required for a carpet plot design study, the payload and performance specifications of the helicopter are needed. This data is used to tailor the equations for the design.

The equations will be developed here for a four-place light helicopter. The equation development procedure is applicable to other size helicopters; the development for a medium helicopter, 20,000 lb weight class, is to be found in Appendix B.

The following specification requirements which are similar to those in Reference 5 will apply to this design:

1. The rotor diameter should be less than 35.2 feet.

2. The overall length should be less than 41.4 feet.

3. The gross weight of the helicopter should not exceed 2,450 lbs.

4. The helicopter should be capable of hovering, out of ground effect at 6,000 feet with an ambient air temperature of 95°F.

5. The useful load at hover shall consist of, as a minimum, 200 lbs for the pilot, 400 lbs of payload and sufficient fuel to give the helicopter up to three hours endurance at sea level conditions.

6. Maximum speed of at least 110 knots using Normal Rated Power, at sea level.

7. Total Power Required at 6,000 feet and 95°F shall be not more than 206.

D. HOVER EQUATIONS

1. The main rotor power required to hover out of ground effect is

Total Main Rotor Power [Hover] = Rotor Profile Power + Rotor Induced Power

$$P_T = \frac{1.13W}{550B\sqrt{2\rho_o}} \sqrt{\frac{DL}{\rho/\rho_o}} + \frac{6WV_T}{4400} \frac{\rho/\rho_o}{C_{LRo}} \left[\delta_0 + \delta_2 \left[\frac{C_{LRo}}{\alpha\rho/\rho_o} \right]^2 \right] \quad (3.1)$$

At an altitude of 6,000 feet and a temperature of 95° , ρ/ρ_o = .749395 . Therefore, equation (1) can be simplified to:

$$P_{T6000/95^{\circ}F} = .035479W[DL]^{1/2} + \frac{.91971}{C_{LRo}} [10]^{-5}(1 + 1.80779\, C_{LRo}{}^2)W\, V_T \quad (3.2)$$

The tail rotor thrust required to counterbalance the main rotor torque is:

$$T_{TR} = \frac{550\ P_T R}{\ell_{TR}\ V_T} = \frac{550\ P_T}{1.19V_T} \qquad (3.3)$$

where ℓ_{TR} has been defined as 1.19R . With R_{TR} defined as .16R , the tail rotor disk loading can be written, using equation (3) as:

$$DL_{TR} = \frac{T_{TR}}{A_{TR}} = \frac{550\ P_T}{1.19V_T} \frac{1}{\pi(.16R)^2}$$
$$= \frac{550\ P_T}{1.19(.0256)V_T} \frac{DL}{W} \qquad (3.4)$$

Greenfield [Ref. 5], in his development, assumes that the tail rotor tip speed is equal to the main rotor tip speed and that $\delta_{TR} = .02$ and $\beta_{TR} = .90$. With these assumptions the equation for the tail rotor power required to hover can be written as:

$$P_{T_{TR_{Hover}}} = 2055.7 \left[\frac{DL}{W\ \rho/\rho_o}\right]^{1/2} \left[\frac{P_{T_{Hover}}}{V_T}\right]^{3/2} + \frac{.012605\ P_{T_{Hover}}}{C_{LRTR}} \qquad (3.5)$$

The equation for the tail rotor mean blade lift coefficient can be written as

$$C_{LRTR} = \frac{P_T}{562.5(\rho/\rho_o)} \qquad (3.6)$$

if it is assumed that the tail rotor is designed to counterbalance a sea level main rotor torque equivalent to 90 percent of the installed power.

Substituting equation (3.6) into equation (3.5) one obtains the following expression for hover tail rotor power:

$$P_{T_{TR6000/950}} = 2374.7 \left[\frac{DL}{W} \right]^{1/2} \left[\frac{P_{T_H}}{V_T} \right]^{3/2} + 5.3134 \qquad (3.7)$$

It is assumed that the gear losses amount to 3 percent and that there is a 1 percent cooling power loss, the total brake horsepower required to hover becomes:

$$P_T = \frac{P_{Tm} + P_{TTR}}{96} \qquad (3.8)$$

Empirical studies have shown that the tail rotor power required to hover can be approximated by

$$P_{T_{AC}} \sim .8 \text{ [total horsepower to hover]}$$

This allows one to write the main rotor power required to hover as:

$$P_{Tm} = (.88)(P_{Tm}) \qquad (3.9)$$

Following Greenfield's [Ref. 5] development further, if equations (3.2) and (3.7) are substituted in equation (3.8), one obtains

$$P_{T_{H6000/95^{o}}} = .036757\ W\ \sqrt{DL}$$

$$+ \frac{.95803}{C_{LRo}}\ (10)^{-5}\ [1 + 1.80779\ C_{LRo}{}^{2}]\ W\ V_T \qquad (3.10)$$

$$+ 2473.6\ \sqrt{\frac{DL}{W}} \left[\frac{P_{Tm}}{V_T} \right]^{3/2} + 5.5348$$

Utilizing the approximation for tail rotor power, equation (3.9), equation (3.10) can be solved for W (gross weight) as a function of variables V_T (tip speed), DL (rotor disk loading), C_{LRo} (rotor mean lift coefficient) and P_{T_H} (total power to hover).

$$W = \frac{K_1 \left[1 - 411.51\ \frac{DL^{3/4}}{V_T{}^{3/2}} \left(1 + K_2\ \frac{V_T}{\sqrt{DL}} \right)^{1/2} \right] - K_3}{V_T + K_4\ \sqrt{DL}} \qquad (3.11)$$

where:

$$K_1 = P_{T6000/90^{o}}\ \frac{(10)^{5}}{K_5} \qquad (3.11a)$$

$$K_2 = \frac{.00025929}{C_{LRo}}\ (1 + 1.80779\ C_{LRo}{}^{2}) \qquad (3.11b)$$

$$K_3 = \frac{553480}{K_5} \tag{3.11c}$$

$$K_4 = \frac{3695.7}{K_5} \tag{3.11d}$$

$$K_5 = \frac{.95803}{C_{LRo}} (1 + 1.80779\ C_{LRo}{}^2) \tag{3.11e}$$

Equation (3.11) has been programmed in Appendix B and solved for tip speeds from 600 to 700 cps and C_{LR} of .3 to .7.

Equation (3.11) is one of the two primary equations used to obtain the data required for a carpet plot design analysis. Generally, the variables V_T, DL, C_{LRo} and P_T, that are required for solution have specific ranges of values, depending on the weight class of the helicopter being designed. The graphical results of equation (3.11) for tip speeds of 600 to 700 fps and mean lift coefficients between .3 and .7 are illustrated in Figure 3.1.

Both the Fortran and Disspla programs, as well as a decision making flow chart are provided in Appendix C to aid in using this method for a design solution.

E. WEIGHT EQUATIONS

Weight equations need to be developed that realistically reflect the sizing class of the helicopter being designed. The evolution is greatly simplified if a specific engine

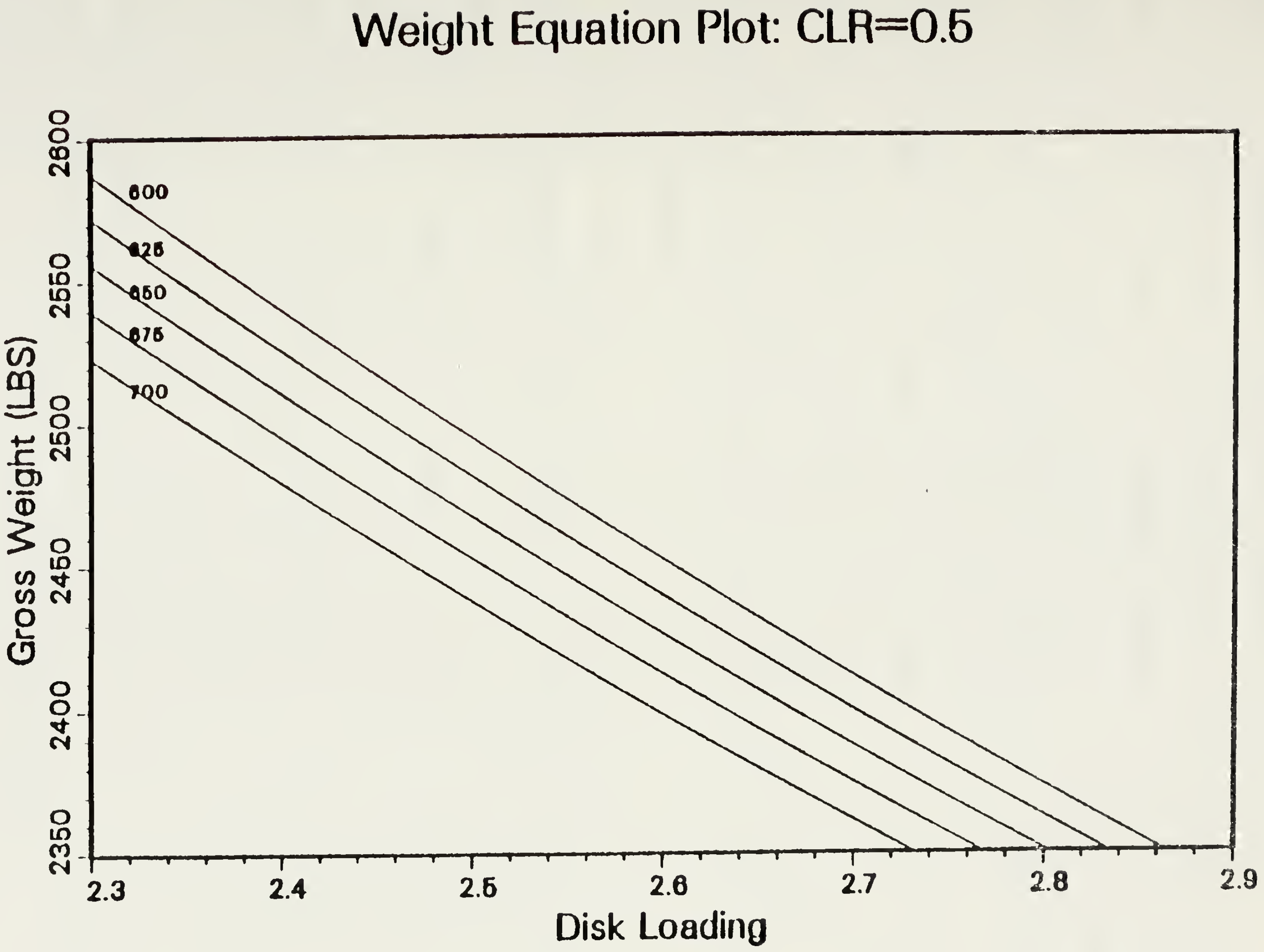

Figure 3.1. Weight Equation Plot: $C_{LR} = 0.5$

installation [# and horsepower] is assumed, since the weight of a number of components depend only on the installed power; this would include such terms as the engine controls and accessories. Another category would be those components whose weights depend on either the gross weight on two or more of the following in combination: rotor tip speed (V_T), rotor diameter (R), rotor solidity (σ).

The equations developed here are taken from the Hiller Aircraft Corporation Performance Data Report. [Ref. 5] In this report they assumed a specific engine installation, the Allison T-63 with a military power rating at sea level of 250 horsepower.

There is a possible problem of the validity of these weight relationships when applied to different helicopter design categories. However, assuming a specific engine determines a number of the component weights, and thus minimizes the inaccuracies. Using the weight estimation relationships developed in the Helicopter Design Manual [Ref. 2], the engine, control and accessory weight can be calculated and the weight formulas developed here applied to give a representative useful load and empty weight formula for preliminary design analysis. This is done in Appendix C, for a 20,000 pound class helicopter.

The following relations are used to reduce the component weight formulas for the specification helicopter:

$$W/DL = A = \pi R^2 \tag{3.12}$$

$$W/PL = MHP = 250 \tag{3.13}$$

(Military rating for Allison T-63 at sea level.) (PL = Power Loading.)

$$P = \sqrt{A}/V_T \tag{3.14}$$

Using these equations the component weight for the specified helicopter empty weight may be reduced to the following:

Engine, Controls and Accessories = 617.5 lbs.

Engine Section Group

$$.053[W/PL]^{1.07} = 19.5 \text{ lbs.} \tag{3.15}$$

Main Transmission

$$10.43 \frac{W^{1.295}}{(PL\ V_T)^{.863}} = 1221\ p^{.803} \tag{3.16}$$

Rotor Drive Shaft

$$5.56 \frac{W^{1.05}}{(PL\ V_T)^{.7}(DL)^{.35}} = 266\ p^{.7} \tag{3.17}$$

Tail Rotor

$$32.22 \frac{W^{1.14}}{(PL\ V_T)^{1.7}} = \frac{17449}{V_T^{1.14}} \tag{3.18}$$

The engine, controls and accessories category includes such items as lubrication and oil cooling system, engines, communications, engine controls, engine accessories, instruments starting system, furnishing, flight controls, electrical system and stabilization. These are considered fixed weight items determined from specification of the engine and weight class of the helicopter.

Tail Rotor Gear Box

$$3.7 \frac{W^{.75}}{(PL\ V_T^{.5}(DL)^{.25}} = 59.47 \sqrt{P} \tag{3.19}$$

Tail Rotor Drive Shaft

$$.124 \frac{W^{1.355}}{(PL\ V_T)^{.57}(DL)^{.785}} = 2.886\ P^{.57} \sqrt{A} \tag{3.20}$$

Body and Gear Landing

$$= 1.91\ W^{.916} + .0294\ W^{.99}$$

Rotor Blade Teetering

$$35.15 \frac{W^{1.185}\sigma^{.33}}{V_T(DL)^{.185}} = 35.15 \frac{W}{V_T} A^{.185}\sigma^{.33} \tag{3.21}$$

Rotor Blade Articulated

$$19.77 \frac{W^{1.205}\sigma^{.33}}{V_T(DL)^{.205}} = 19.77 \frac{W}{V_T} A^{.205}\sigma^{.33} \tag{3.22}$$

Rotor Hub Teetering

$$.0088 \frac{W^{1.21}}{DL^{.21}} = .0088\ WA^{.21} \tag{3.23}$$

Rotor Hub Articulated

$$.00975 \frac{W^{1.21}}{DL^{.21}} = 00975\ WA^{.21} \tag{3.24}$$

Fuel System .416 per gallon capacity = .0615 W_F (3.25)

where W_F = fuel weight.

The individual component weights may now be combined into a single expression for the helicopter empty weight.

$$W_e = 617.5 + .0617W_F = 1221P^{.863} + 266P^{.7} + \frac{17449}{V_T^{1.14}} \qquad (3.26)$$

$$+ 58.47\sqrt{P} + 2.886P^{.57}\sqrt{A} + .191W^{.916} + .0294W^{.99}$$

+ appropriate rotor blade and hub weights.

As stated earlier, the design specifications called for a useful load consisting of a pilot (200 lbs), payload (400 lbs) and the required fuel weight (W_F). The fuel weight is calculated for the Allison T-63 in the following manner: endurance of three hours at 85 percent of normal rated powered for the T-63 is 180.2 HP and the specific fuel consumption at this power is .783 lbs fuel/BHP HR. Including an allowance for a three-minute warm-up at NRP and using a 5 percent correction factor on SFC, as specified in Reference 5, the fuel weight becomes:

$$W_F = 3(180.2)(.822) + \frac{3}{60}(212)(777) \qquad (3.27)$$

An allowance should also be made for oil plus trapped fuel. This is estimated at 20 lbs.

The total useful load is the sum of the useful load items.

$$W_u = 200 + 400 + 452.6 + 20 = 1072.6 \text{ lbs} \qquad (3.28)$$

A new variable, W_{BAR} , is defined as the sum of the emply weight plus useful load. It is the of equations (3.26) and (3.28).

$$W_{BAR} = 1717.9 + 1221P^{.863} = 266P^{.7} + \frac{17449}{V_T^{1.14}} + 58.47\sqrt{P}$$

$$+ 2.886P^{.57}\sqrt{A} + .191W^{.916} + .0294W^{.99} \qquad (3.29)$$

+ appropriate rotor blade and hub weights.

Equation (3.11) together with equation (3.29) form the basis of a carpet plot design study. These equations are solved simultaneously for W_{BAR} . This solution is best illustrated graphically, as in Figure 3.2. The graph in Figure 3.2 was generated for a specific value of C_{LR} over a range of tip speeds [600 to 700].

F. GRAPHICAL ANALYSIS

Graphs similar to Figure 3.1 are generated for several value of C_{LR} , and are then cross plotted to form Figure 3.2.

The mean lift coefficient, C_{LR} , values are selected based on what is considered the historical average range of

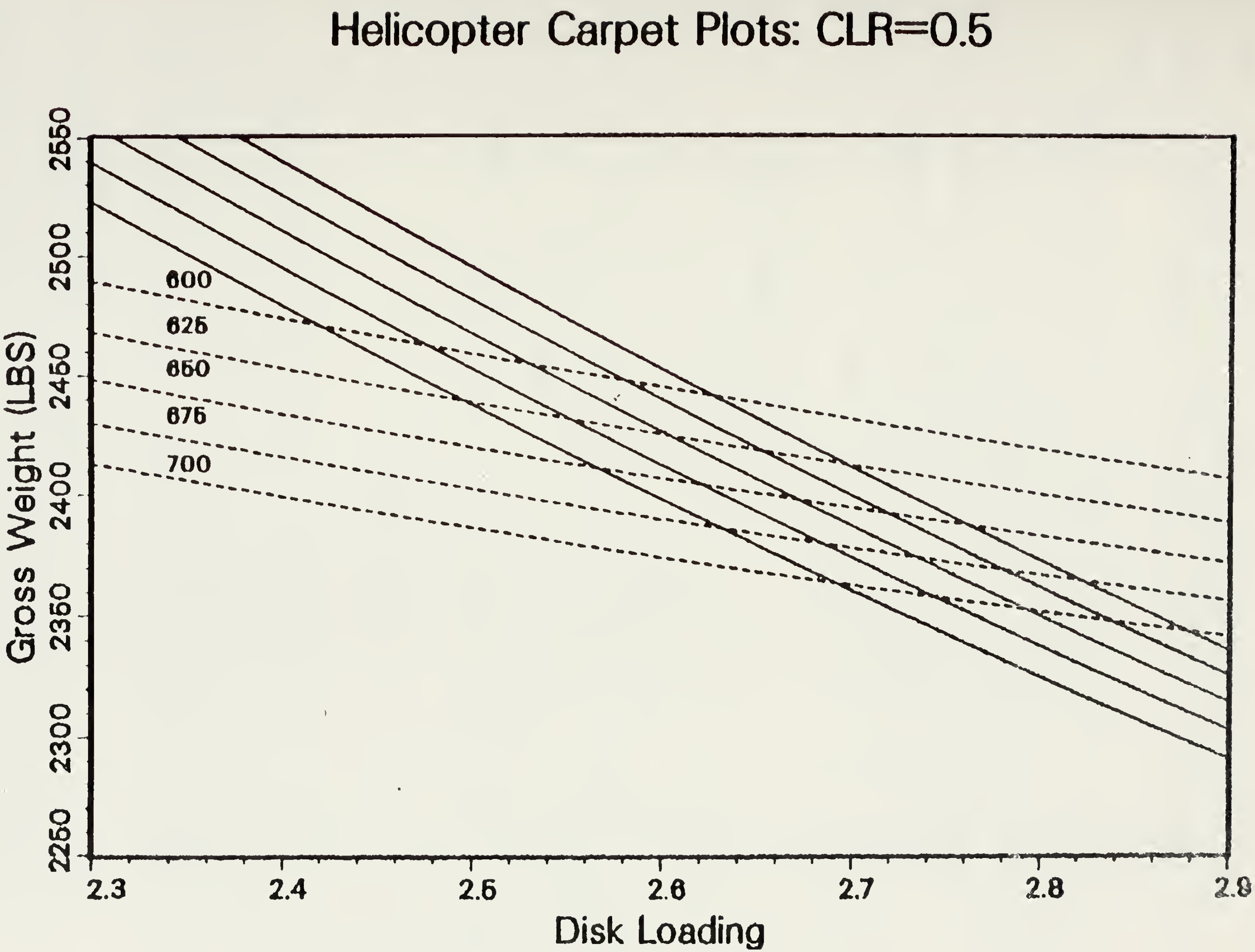

Figure 3.2. Helicopter Carpet Plots: $C_{LR} = 0.5$

values. Figure 3.3 is basic plot for a carpet plot design study. Programs are provided in Appendix D which will generate the required data sets and plots of Figures 3.2 and 3.3.

The solution field depicted in Figure 3.3 is too large to be of great analytic value and as such must be reduced. Three parameters, maximum gross weight, rotor diameter (both specified in the Design Specification) and the aspect ratio can be used to narrow the field of solutions.

1. Rotor Diameter Boundary

A net to exceed value for the rotor diameter is generally given in the design specifications. This limiting value is based on the operating environment of the helicopter. With R max specified, there is a linear relationship between the disk loading and the gross weight.

$$DL = \frac{W}{A} = \frac{W}{\pi R^2}$$

The resulting bracketing of the solution field by applying both the maximum gross weight and maximum rotor diameter limits to the carpet plot are shown in Figure 3.4.

2. Respect Ratio Boundary

It is evident that a further restriction is still necessary to completely define the region of acceptable

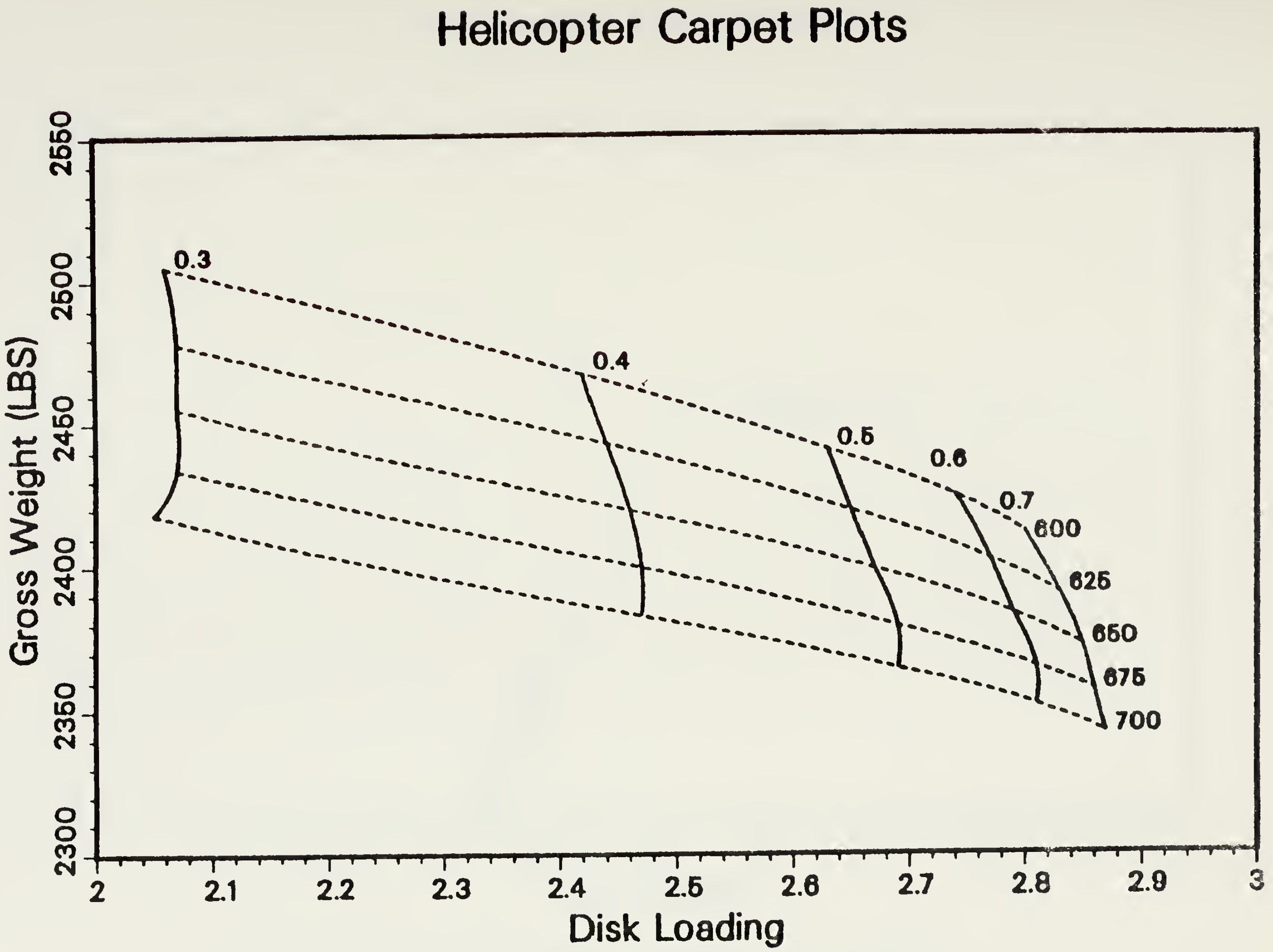

Figure 3.3. Helicopter Carpet Plots
Family of Solutions

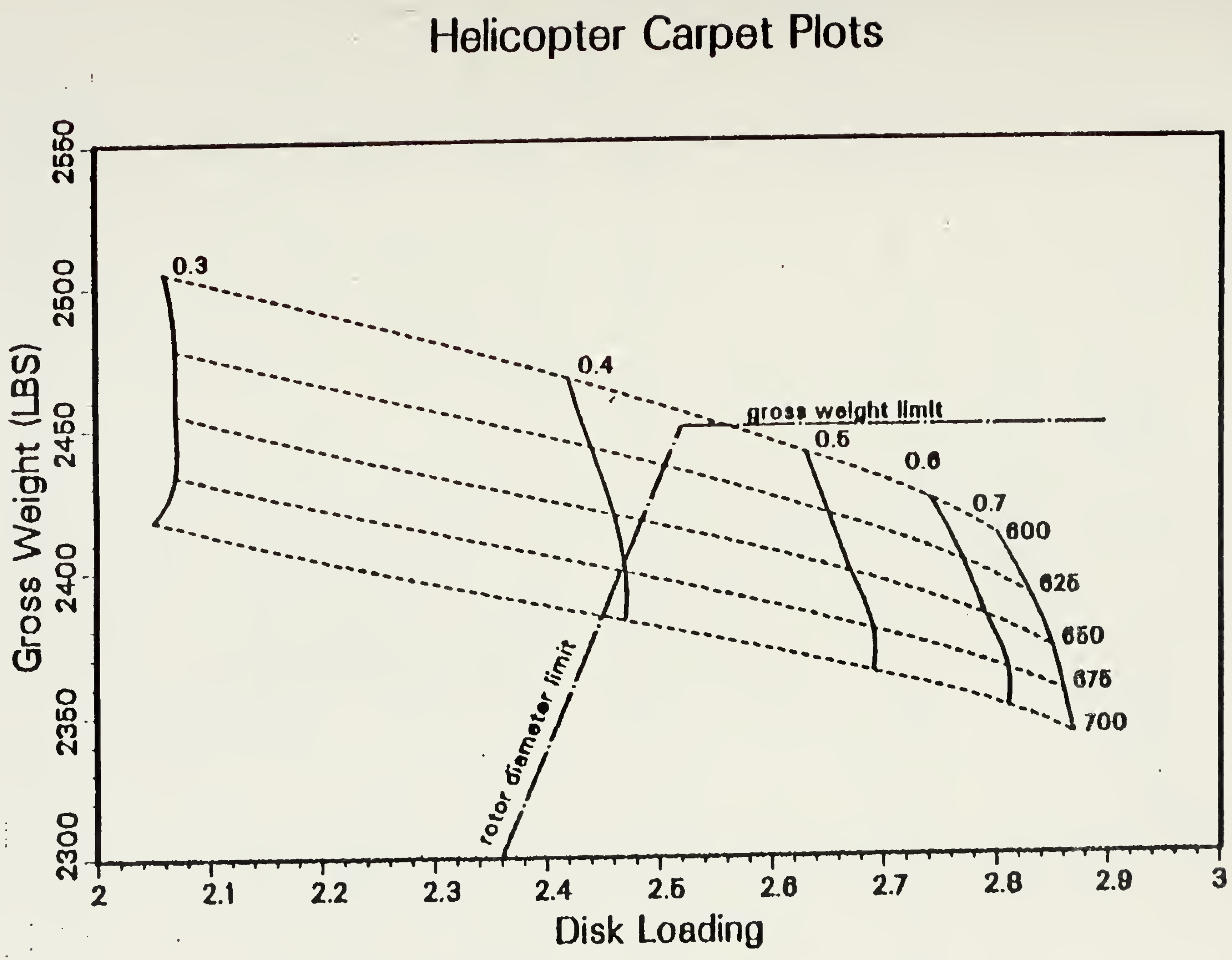

Figure 3.4. Helicopter Carpet Plots Rotor Diameter and Weight Limits

design solutions. Studies have indicated that a main rotor aspect ratio of 21,[1] is a representative upper limit. Thus

$$21 \geq \frac{R\langle mr\rangle}{C\langle mr\rangle} = \frac{b}{\pi\sigma} = \frac{b\ \rho_o\ C_{LR}\ V_T^{\ 2}}{\sigma\pi\ DL}$$

or

$$DL \geq \frac{b\ \rho\ C_{LR}\ V_T^{\ 2}}{126\pi}$$

For the case of a two bladed main rotor equation (3.30) reduces to:

$$DL \geq .000012\ C_{LR}\ V_T^{\ 2}$$

The detemination of this boundary graphically is as follows:

The hover solution plot of Figure 3.2 is replotted[2] relative to the coordinates disk loading and design mean blade lift coefficient. The limiting curves for $DL = .000012\ C_{LR}\ V_T^{\ 2}$ are then plotted. The intersection with the appropriate constant tip speed lines of the hover solution represent the aspect ratio boundary; Figure 3.5.

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[1] For a helicopter rotor, the aspect ratio is defined as the radius divided by the chord.

[2] For clarity lines of constant gross weight are omitted.

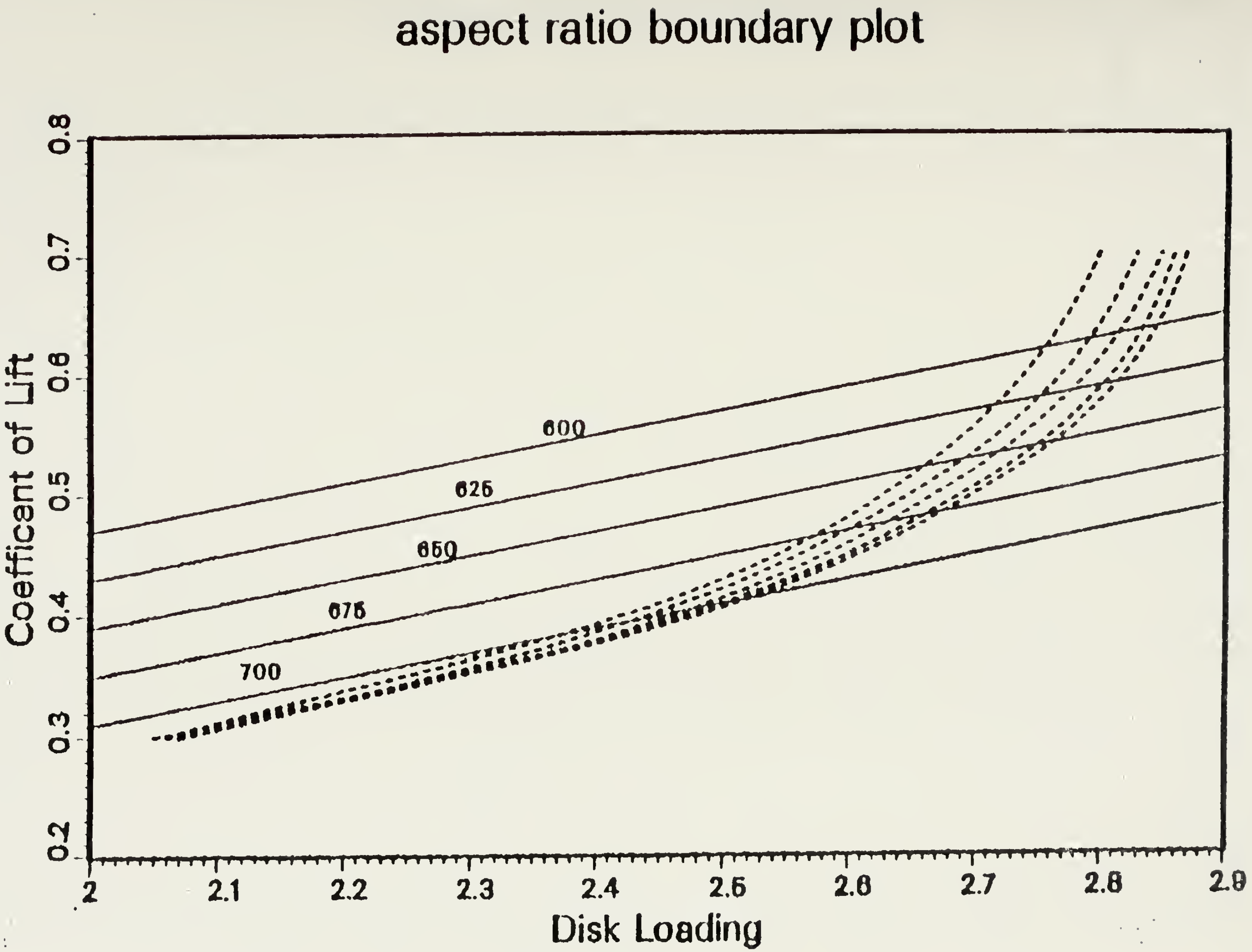


Figure 3.5. Aspect Ratio Boundary Plot

These intersection points are then cross plotted onto Figure 3.4. Figure 3.6 represents a graphical plot of the solution set satisfying the performance and structural design criteria of a small observation helicopter as specified in this study.

Helicopter Carpet Plots

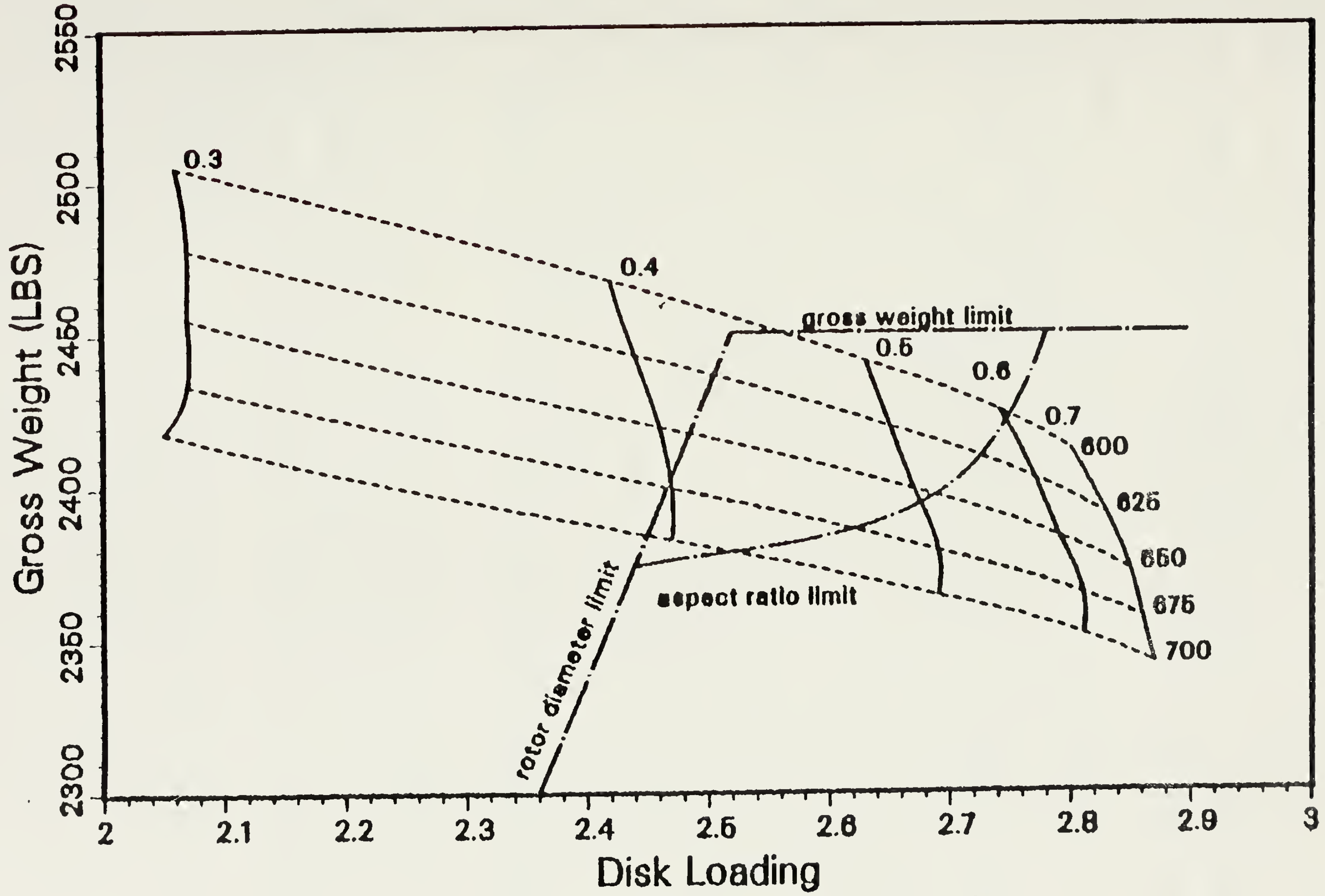


Figure 3.6. Helicopter Carpet Plots
Final Solution

IV. HESCOMP

A. DESCRIPTION OF PROGRAM

HESCOMP is a helicopter sizing and performance computer program developed by the Boeing Vertol Company. The program was originally formulated to provide for rapid configuration design studies.

A number of programming options are available to the user of HESCOMP. When the type and mission profile of the helicopter are known, HESCOMP may be used to size the aircraft. Alternately, it may be used for mission profile calculations when the sizing details [gross weight, payload, engine size, etc.] are specified. A combination of these two options is also available; the program may be used to first size a helicopter for a primary mission and then calculate the off-design performance for other missions. Finally, HESCOMP may be used solely for obtaining helicopter weight.

Sensitivity studies involving both design and performance tradeoffs can easily be done with HESCOMP. Incremental multiplicative and additive factors can be imbedded in the input data.

The various helicopter configurations that may be studied using HESCOMP are detailed in Table 4.1.

TABLE 4.1

HELICOPTER CONFIGURATIONS WHICH MAY BE STUDIED USING HESCOMP

HELICOPTER CONFIGURATIONS WHICH MAY BE STUDIED USING HESCOMP.

Additional Lift/Propulsion System Components Which Must be Added to "Pure" Conf. Helicopter Type (Both Single & Tandem Rotor)	Wing	Propeller for Auxiliary Propulsion	Auxiliary Independent Engines	Type of Auxiliary Independdnt Engines		
				T/Shaft	T/Fan	T/Jet
Pure Helicopter						
Winged Helicopter	X					
Compound Helicopter						
(1) Coupled (prim. engines drive auxiliary propulsion system)	X	X				
(2) Auxiliary independent propulsion system						
(a) T/Shaft engine	X	X	X	X		
(b) T/Fan engine	X		X		X	
(c) T/Jet engine	X		X			X
Auxiliary Propulsion Helicopter						
(1) Coupled (prim. engines drive auxiliary propulsion system)		X				
(2) Auxiliary independent propulsion system						
(a) T/Shaft engine		X	X	X		
(b) T/Fan engine			X		X	
(c) T/Jet engine			X			X
oaxial Rotor Helicopter						
(1) Coupled (prim. engines drive auxiliary propulsion system)		X				
(2) Auxiliary independent propulsion system						
(a) T/Shaft engine		X	X	X		
(b) T/Fan engine			X		X	
(c) T/Jet engine			X			X

B. PROGRAM MODIFICATIONS AND IMPLEMENTATION

The computer program received from Boeing Vertol required some modification and reformating in order to run properly on the Naval Postgraduate School IBM system. These alterations did not, however, alter the program output or usability.

HESCOMP, as received from Boeing Vertol, was 17821 lines long and set-up as a sequential data set to be assemble on a 'G compiler'. The Batch processing system at the Naval Postgraduate School accepts only programs set to run on 'H compiler'. Normally, the differences between these two compilers are minor and programs that run on one will run on the other. However, this was not the case with HESCOMP.

In order to facilitate the program debugging process, HESCOMP was reformatted as a partitioned data set. What this effectively did was to break the program down into eight members of approximately 2000 lines. The program breakdown is illustrated in Table 4.2.

Each of these were compiled individually and then error codes analyzed. The member data set was then modified as required to properly compile.

Once all the members of the partitioned data set compiled properly, HESCOMP was again formated as a sequential data set and run utilizing input data for

which there was a known output. This insured that the modifications made to the original program had not altered the logic, ie., gave faulty results.

The control language program to access HESCOMB on the Batch processing system and a sample input and out data set are shown in Appendix D. These are also available on the Aero disk for copying and use.

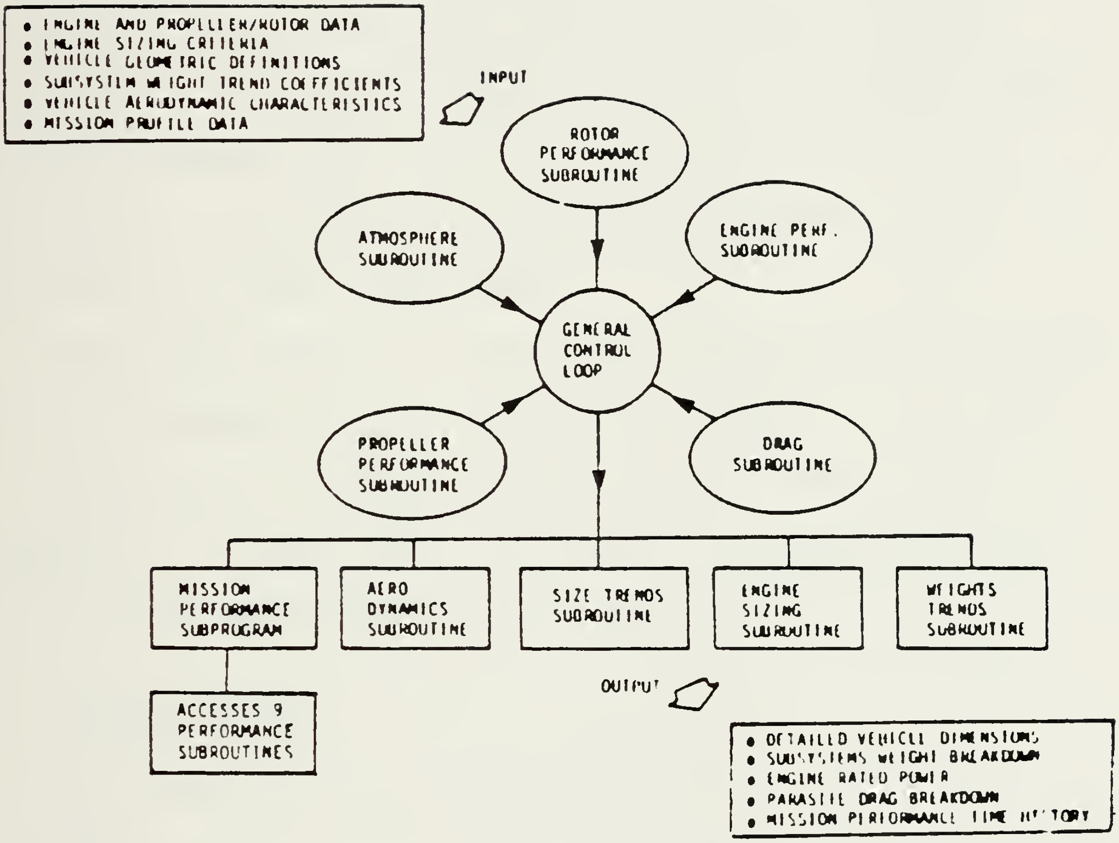
TABLE 4.2

PARTITIONED DATA SET

MEMBER NAME	LINE NUMBER	SIZE	FIRST ROUTINE
S1	1 - 1681	1681	AERO
S2	1682 - 4132	2451	CLIMB
S3	4133 - 6531	2399	XIBIV
S4	6532 - 8974	2443	POWAVL
S5	8975 - 10870	1896	PRINT 1
S6	10871 - 13042	2172	ROT POW
S7	13043 - 15383	2341	CRUS 3
S8	15384 - 17821	2448	TAXI

C. PROGRAM FLOW

The program is conceptually outlined in Figure 4.1, [Ref. 7]. The program flow is monitored by a general loop, which controls a series of peripheral programs. There are



• ENGINE AND PROPELLER/ROTOR DATA
• ENGINE SIZING CRITERIA
• VEHICLE GEOMETRIC DEFINITIONS
• SUBSYSTEM WEIGHT TREND COEFFICIENTS
• VEHICLE AERODYNAMIC CHARACTERISTICS
• MISSION PROFILE DATA
INPUT
ROTOR PERFORMANCE SUBROUTINE
ATMOSPHERE SUBROUTINE
ENGINE PERF. SUBROUTINE
GENERAL CONTROL LOOP
PROPELLER PERFORMANCE SUBROUTINE
DRAG SUBROUTINE
MISSION PERFORMANCE SUBPROGRAM
AERO DYNAMICS SUBROUTINE
SIZE TRENDS SUBROUTINE
ENGINE SIZING SUBROUTINE
WEIGHTS TRENDS SUBROUTINE
ACCESSES 9 PERFORMANCE SUBROUTINES
OUTPUT
• DETAILED VEHICLE DIMENSIONS
• SUBSYSTEMS WEIGHT BREAKDOWN
• ENGINE RATED POWER
• PARASITE DRAG BREAKDOWN
• MISSION PERFORMANCE TIME HISTORY

Figure 4.1. HESCOMP Program Flow

a total of 44 subroutines. Detailed program descriptions cam be found in Section 4 of the HESCOMP User's Manual.

D. PROGRAM INPUT

Program input can be loosely group into ten categories: general information, aircraft descriptive information, mission profile information, rotor tip speed schedule, incremental rotor performance, auxiliary propulsion input schedule, engine cycle information, rotor performance information, propeller performance information, and supplementary input information.

The actual amount of input data requires varies greatly with the program options selected. An example of a data set formatted to run on the IBM system is shown in Appendix E. A more detailed explantion is available in Section 5 of the HESCOMP User's Manual.

E. PROGRAM OUTPUT

An example of the program output is included in Appendix E. The printout consists of general data, input data, sizing data [program output] and mission performance data [for the size helicopter]. Detailed descriptions of these and diagnostic error statements are described in Section 6 of Reference 6.

V. CONCLUSIONS AND RECOMMENDATIONS

Three approaches to analyzing a preliminary helicopter design were explored in the course of this paper. It was found that a number of the performance equations could be greatly simplified with little degradation in the final results. A sensitivity analysis brought further insight into the inter-play of the parameters and how changes in them tended to effect the helicopter performance equations.

Carpet Plots provided the most interesting method of analysis. Development of a graphical solution matrix using this method provides a usual interpretation of what is occurring when key parameters are varied.

Two cases were explored; a light observation helicopter in the 3,000 pound weight class and a heavier utility helicopter in the 20,000 pound weight class. The Carpet Plot method provided reasonable solutions in both cases. In doing the analysis for the utility helicopter, the initial weight estimation equation had to be adjusted upward by approximately 2,000 pounds for the equations to intersect properly. This is not considered a limitation to this method of analysis, however, it does point up an area for further investigation. It may be possible to develop more accurate weighing factors for this equation when dealing with higher gross weight helicopters.

HESCOMP provides a plethora of information to the user. However, the price is the amount of inputed data required for even a simplified analysis. At a preliminary design level of analysis, the other methods explored provide a quicker first-cut look at the potential design.

APPENDIX A: NOMENCLATURE

TERM	DEFINITION	UNITS
a	Slope of Airfoil Section Lift Curve	Radians
A	Rotor Disk Area	ft^2
AR	Aspect Ratio	Dimensionless
A_{TR}	Tail Rotor Disk Area	ft^2
b	Number of Rotor Baldes	Dimensionless
B	Tip Loss Factor	Dimensionless
C	Main Rotor Cord	ft
C_{do}	Profile Drag Coefficient at Zero Lift	Dimensionless
C_{LRo}	Design Mean Blade Lift Coefficient at Sea Level	Dimensionless
C_T	Coefficient of Thrust	Dimensionless
C_p	Coefficient of Power	Dimensionless
δ	Blade Section Drag Coefficient	Dimensionless
DL	Disk Loading	lb/ft^2
FM	Figure of Merit	Dimensionless
HP	Horsepower	
L_{TR}	Tail Rotor Moment Arm	ft
ρ	Air Density	$lb\ sec^2/ft^4$
μ	Advance Ratio	Dimensionless
R	Rotor Radius	ft

TERM	DEFINITION	UNITS
P_T	Total Power	HP
P_{TM}	Main Rotor Total Power	HP
P_{TTR}	Tail Rotor Total Power	Hp
P_o	Profile Power	HP
P_i	Induced Power	HP
P_p	Parasite Power	HP
PL	Power Loading	LB/HP
R	Rotor Radius	ft
T	Thrust	HP
V_I	Induced Velocity	ft/sec
V_F	Forward Velocity	ft/sec
V	Aircraft Forward Speed	ft/sec
V_T	Rotor Tip Speed	ft/sec
W	Aircraft Gross Weight	lbs
W_c	Empty Weight	lbs
W_F	Fuel Weight	lbs
W_u	Useful Load	lbs
W_{BAR}	Empty Weight Plust Useful Load	lbs
σ	Solidity	Dimensionless

APPENDIX B: CARPET PLOT FORMULATION FOR 20,000 LB. CLASS HELICOPTER

B1 SPECIFICATIONS:

Maximum Gross Weight: 20,000 pounds
Maximum Rotor Diameter: 30 feet

B2 PRELIMINARY ENGINE SIZING:

B2.1 Utilize equation (2.14) to determine engine horsepower category.

$$W = [4.753P_TR]^{2/3}$$

$$20{,}000 = [47.53P_T\ 30]^{2/3}$$

$$P_T = 1983\ \text{HP}$$

B2.2 Use the engine selection parameters tables B.1 to determine the number and type of power plant [table taken from Reference 3].

B2.2a Type and number selected: 2 type C.

B2.2b Specifications:

Dry Weight Per Engine: 423 pounds

Shaft Horsepower at Standard Sea Level:

Military	1561 HP
Normal	1318 HP

B3 WEIGHT EQUATION FORMULATION

B3.1 To obtain the engine control and accessory weight use items 7, 9, 10, 11, 12 and 13 of the weight estimation relationships developed in Reference 3 for a utility helicopter: #7: 609 lbs; #9: 129 lbs; #10: 76 lbs; #11: 410 lbs; #12: 439 lbs; and #13: 302 lbs.

TABLE B.1

ENGINE SELECTION PARAMETERS

The following turboshat power plant data are presented for one engine.

Engines:		A	B	C	D*	E	F
Dry Weight (lbs)		158	288	423	709	580	750
SHP (ssl)	Military	420	708	1561	1800	2500	3400
	Normal	370	659	1318	1530	2200	3000
	Cruise	278	494	1989	1148	1650	2250
SFC (ssl)	Military	.650	.573	.460	.595	.615	.543
	Normal	.651	.573	.470	.606	.622	.562
	Cruise	.709	.599	.510	.661	.678	.610
Initial Costs		$93K	$100K	$580K	$360K	$640K	$700K
Operating Cost per hour/engine		$8	$16	$20	$35	$40	$60
Preventative Maint per hour/engine		$25	$50	$100	$125	$160	$220
MTBMA (hrs)		3.5	3.0	2.0	3.0	4.0	3.5
MDT (hrs)		0.7	0.6	0.5	1.3	2.0	2.6
MTBF (hrs)		185	210	205	285	280	320
MTBR (hrs)		600	750	800	800	1000	750

B3.2 Simplifications

$$\frac{W}{DL} - A = \pi R^2 \quad , \quad \frac{W}{\ell pm} = MHP = 31,00 \; ; \quad P = \sqrt{\frac{A}{V_T}}$$

B3.3 Engine Group

$$.053(5100)^{1.07} = 272 \text{ lbs}$$

B3.4 Main Transmission

$$10.43 \frac{W^{1.295}}{(\ell pm\ V_t)^{.863} \left[\frac{W}{A}\right]^{.432}} = 10.43 \frac{W^{.863}\ A^{+.432}}{(\ell pm)^{.863} V_T^{\ .863}}$$

$$= (10.43)(3100)^{.863} P^{.863}$$

$$= 10,748P^{.863}$$

B3.5 Rotor Drive Shaft

$$5.56 \frac{W^{1.05}}{(\ell pm\ V_T)^{.7} \left[\frac{W}{A}\right]^{.35}} = 5.56(3100)^{.7} P^{.7}$$

$$= 1545P^{.7}$$

B3.6 Tail Rotor

$$32.22 \frac{W^{1.14}}{(\ell pm\ V_T)^{1.14}} = \frac{307,600}{V_T^{\ 1.14}}$$

B3.7 Tail Rotor Gear Box

$$3.7 \frac{W^{.75}}{(\ell pm\ V_T)^{.5} \left[\frac{W}{A}\right]^{.25}} = (3.7)(3100)^{.5}P^{.5}$$

$$= 206P^{.5}$$

B3.8 Tail Rotor Drive Shaft

$$.124 \frac{W^{1.355}}{(\ell pm)^{.57} \frac{W^{.785}}{A^{.785}}} = (.124)(3100)^{.57}P^{.57} \sqrt{A}$$

$$= 12.12P^{.57} \sqrt{A}$$

B3.9 Landing Gear

$$= .191W^{.916} + .0294W^{.99}$$

B3.10 Rotor Blades Articulated

$$19.77 \frac{W^{1.206}\sigma^{.33}}{V_T\ DL^{.205}}$$

$$= 19.77 \frac{W}{V_T} A^{.205}\sigma^{.33}$$

B3.11 Rotor Hub Articulated

$$.00975 \frac{W^{1.21}}{DL^{.21}} = .00975WA^{.21}$$

B3.12 Fuel System $.0615\ W_F$

Calculation of fuel weight three hours at cruise SHP

1513 lbs + 10%

1664 lbs

B3.13 Total Equation

$$WB = 12{,}987,^{*} + 107948P^{.863} + 1545P^{.7}$$

$$+ \frac{307600}{V_T^{1.14}} + 206P^{.5} + 12.12P^{.57}\sqrt{A}$$

$$+ .191W^{.916} + .0294W^{.99}$$

$$+ 19.77\frac{W}{V_T}A^{.205}S^{.33} + .00975WA^{.21}$$

B4 HOVER EQUATION

Following the formulation in Section of Chapter 3, the weight equation based on the design mean lift coefficient and power required is:

$$W = \frac{K_2\left[1 - 411.51\frac{DL^{3/4}}{V_T^{3/2}}\left(1 + K_3\frac{V_T}{\sqrt{DL}}\right)^{1/2}\right] - K_4}{V_T + K_5\sqrt{DL}}$$

---

[*] This number was increased from 8987 to 12987 to bring the curves together. This reflects a 4000 lb useful load.

where:

$$K_1 = \frac{.9583}{C_{LRo}} (1 + 1.8078\ C_{LRo}{}^2)$$

$$K_2 = P_{T6000/950}\ \frac{(10^5)}{K_1}$$

$$K_3 = \frac{0.00025929}{C_{LR_o}} \quad (1 + 1.8078 C_{LRo}{}^2)$$

$$K_4 = \frac{553480.0}{K_1}$$

$$K_5 = \frac{3695.7}{K_1}$$

B.5 GRAPHICAL RESULTS

Figure B.1 is an example of equation (3.13) plotted against equation (B.4) for a specific design mean lift coefficient.

Figure B.2 illustrates the family of curves obtained when the design mean lift coefficient is varied from 0.3 to 0.7 .

In Figure B.3 the solution matrix depicted in Figure B.2 is narrowed by the constraints placed on the gross weight, rotor diameter and aspect ratio.

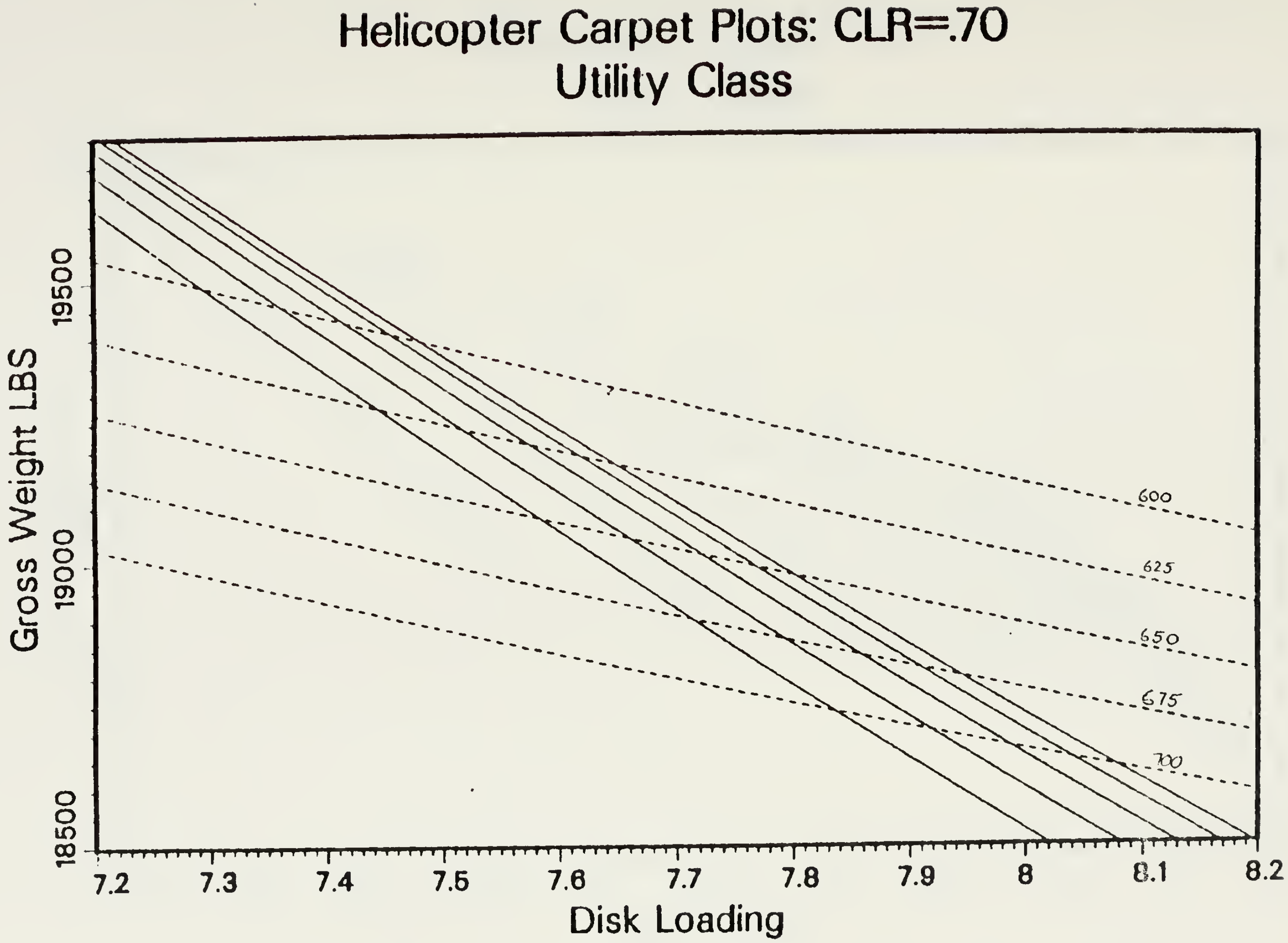

Helicopter Carpet Plots: CLR=.70
Utility Class

Figure B1. Helicopter Carpet Plots: C_{LR} = .70
Utility Class

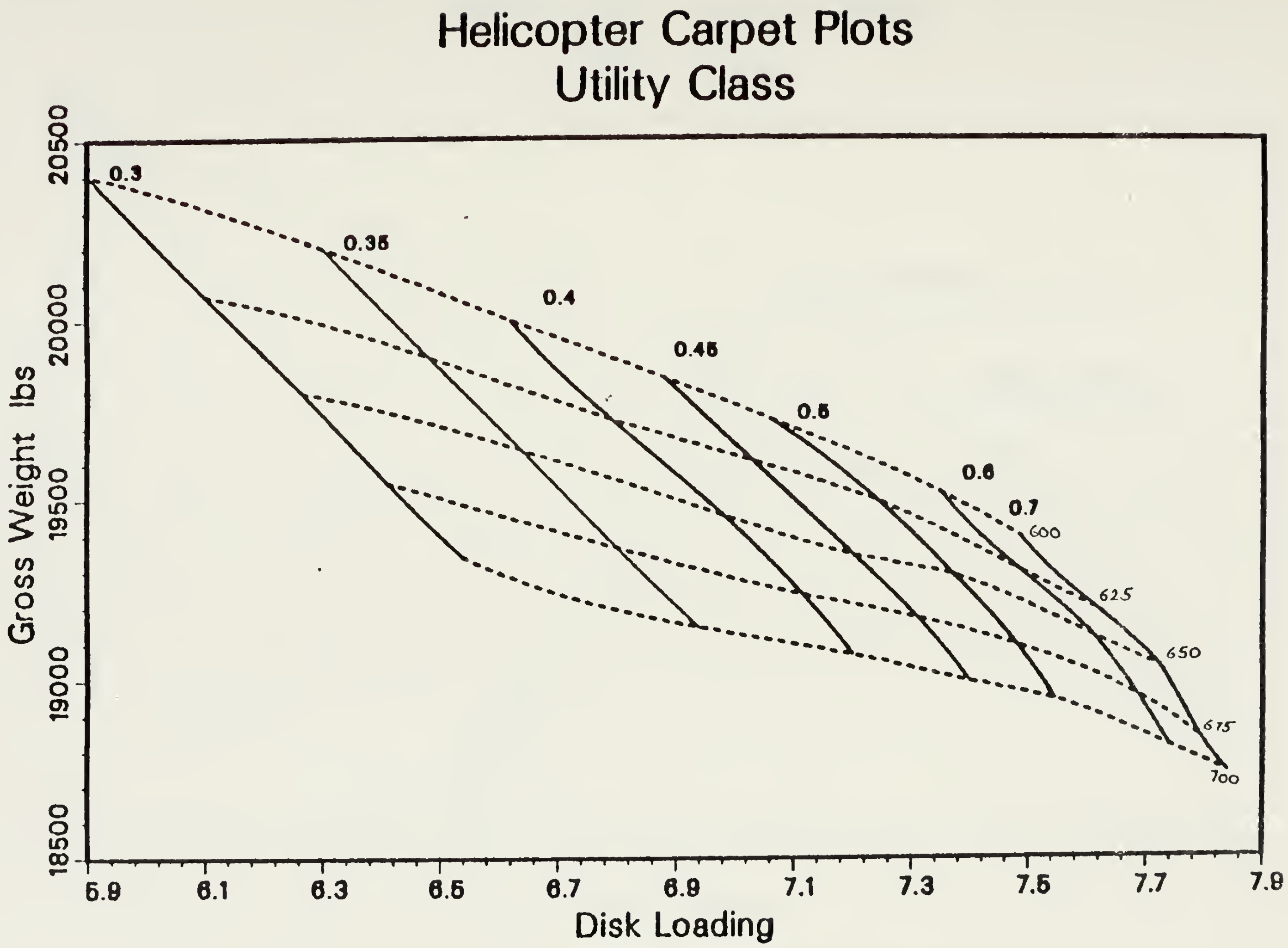


Figure B2. Helicopter Carpet Plots
Utility Class

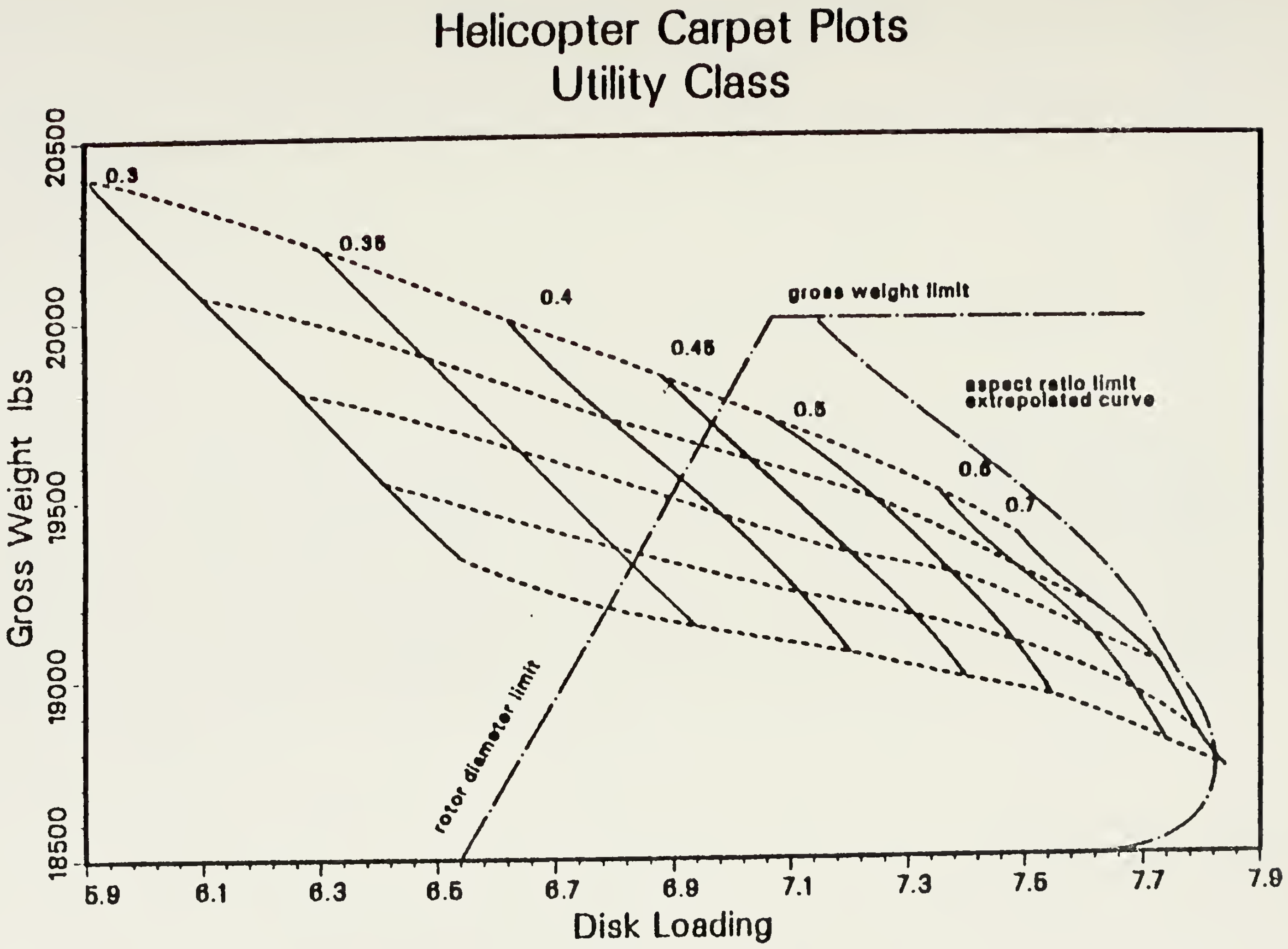
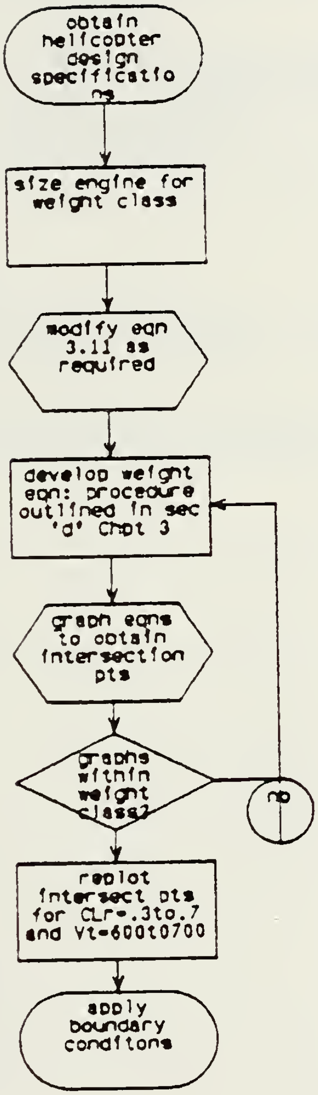


Figure B3. Helicopter Carpet Plots
Utility Class

APPENDIX C. CARPET PLOT METHODOLOGY FLOW CHART AND EXAMPLE PROGRAMS:

This section contains a flow chart to help organize a carpet analysis and example IBM computer programs to produce the data sets and disspla graphs.


obtain helicopter design specifications
size engine for weight class
modify eqn 3.11 as required
develop weight eqn: procedure outlined in sec 'd' Chpt 3
graph eqns to obtain intersection pts
graphs within weight class?
no
replot intersect pts for CLr=.3to.7 and Vt=600to700
apply boundary conditons

```
C*****************************************************************
C*****************************************************************
C**********       GRAPHICAL HELICOPTER DESIGN PROGRAM    **********
C********                CARPET PLOT NUMBER 1             ********
C********                 BY AL HANSEN                    ********
C********                                                 ********
C********    THIS PROGRAM IS DESIGNED TO PROVIDE A WEIGHT VS.  ********
C********      DISK LOADING GRAPH AT SEVERAL DIFFERENT ROTOR   ********
C********      TIP VELOCITIES FOR A SPECIFIED DESIGN MEAN     ********
C********                LIFT COEFFFICENT.                 ********
C**********              OBSERVATION CLASS               **********
C*****************************************************************
C*****************************************************************
C****                                                        *****
C**                          NOMENCLATURE                      ***
C*                                                              **
C*      VARIABLES:                                              **
C*                                                              **
C*      CLR      DESIGN MEAN LIFT COEFFICENT                    **
C*      VT       TIP VELOCITY                                   **
C*      DL       DISK LOADING
C*      W        WEIGHT AS CALCULATED FROM POWER EQUATION       **
C*      WB       USEFUL LOAD PLUS EMPTY WEIGHT                  **
C*      PA       POWER AVAILABLE IN HORSEPOWER                  **
C*                                                              **
C****                                                        *****
C*****************************************************************
      REAL CLR,DL(150),W1(150),W2(150),W3(150),W4(150),W5(150),
     1WB1(150),WB2(150),WB3(150),WB4(150),WB5(150)
C
      INTEGER I
C
C
C---- DEFINE FILES -----------------------------------------------
C
      CALL FRTCMS ('FILEDEF ','3        ','DISK    ','CRPT35',
     1            'DATA    ','A        ')
C
C
      CALL FRTCMS ('FILEDEF ','4        ','DISK    ','CRPT45',
     1            'DATA    ','A        ')
C---- READ DATA FROM FILE: CRPTX DATA A ---------------------------
C
      DO 10 I=1,99
C     CRPT1 DATA A
      READ (3,70) DL(I),W1(I),WB1(I),W2(I),WB2(I)
C     CRPT2 DATA A
      READ (4,71) W3(I),WB3(I),W4(I),WB4(I),W5(I),WB5(I)
10    CONTINUE
C
C---- CALL DISSPLA ROUTINES FOR PLOT ------------------------------
C
      CALL TEK618
      CALL MEDEUF
      CALL RESET (3HALL)
      CALL HWSCAL ('SCREEN')
      CALL PAGE (12.0, 9.5)
      CALL GRACE (0.0)
      CALL PHYSCR (1.0,1.2)
      CALL AREA2D (10.0,6.5)
      CALL FRAME
      CALL SWISSL
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STAND')
      CALL INTAXS
      CALL YTICKS (5)
      CALL XTICKS (5)
      CALL SHDCHR (.90,1,.015,1)
      CALL HEIGHT (.16)
      CALL XNAME ('(D)ISK (L)OADING$',100)
      CALL YNAME ('(G)ROSS (W)EIGHT ((LBS))$',100)
      CALL HEIGHT (.290)
      CALL HEADIN ('(H)ELICOPTER (C)ARPET (P)LOTS: (CLR=0.5)$',
     1            100,1.0,1)
C     CALL MESSAG ('(H)ELICOPTER (C)ARPET (P)LOTS: (CLR=0.5)$',
C    1            100,3.25,7.55)
```

```
      CALL HEIGHT (.20)
      CALL GRAF (2.3,.1,2.9,2250.,50.,2550.)
      IYGRID=5
      CALL THKCRV (.018)
      CALL LEGLIN
      CALL CURVE (DI,W1,95,0)
      CALL CURVE (DI,W2,95,0)
      CALL CURVE (DI,W3,95,0)
      CALL CURVE (DI,W4,95,0)
      CALL CURVE (DI,W5,95,0)
      CALL DASH
      CALL CURVE (DI,WE1,95,0)
      CALL CURVE (DI,WE2,95,0)
      CALL CURVE (DI,WE3,95,0)
      CALL CURVE (DI,WE4,95,0)
      CALL CURVE (DI,WE5,95,0)
      CALL THKCRV (.030)
C     CALL BLREC (4.2,4.65,1.6,1.35,1)
C     CALL GRID (1,IYGRID)
C     CALL BLOFF (1)
      MAXLIN=LINEST(IPAK1,300,20)
      CALL HEIGHT (.12)
      CALL LINESP (2.0)
      CALL LINES ('(W)EIGHTS$',IPAK1,1)
C     CALL LINES ('(I)NDUCED$',IPAK1,2)
C     CALL LINES ('(P)ROFILES$',IPAK1,3)
C     CALL LINES ('(P)ARASITES$',IPAK1,4)
C     CALL MYLEGN ('(P)OWER (C)URVES',16)
C     CALL LEGEND (IPAK1,4,4.43,4.8)
      CALL DONEPL
      STOP
C     FORMAT STATEMENTS
 70   FORMAT (5(2X,F10.3))
 71   FORMAT (6(2X,F10.3))
      END
```

```
C***********************************************************************
C***********************************************************************
C**********      GRAPHICAL HELICOPTER DESIGN PROGRAM          **********
C********                FAMILY OF SOLUTIONS                  *********
C********                CARPET PLOT NUMBER 2                  ********
C********                    BY AL HANSEN                      ********
C********                                                      ********
C********    THIS PROGRAM IS DESIGNED TO ILLUSTRATE THE FAMILY  ********
C********      OF SOLUTIONS FOR HOVER AND USEFUL LOAD           ********
C********      REQUIREMENTS OF A TEETERING ROTOR SYSTEM         ********
C********         WITHOUT ANY BOUNDARY CONDITIONS             ********
C********               OBSERVATION CLASS                      ********
C**********                                                   **********
C***********************************************************************
C***********************************************************************
C****                                                              *****
C**                           NOMENCLATURE                           ***
C*                                                                    **
C*     VARIABLES:                                                     **
C*                                                                    **
C*     CLR      DESIGN MEAN LIFT COEFFICENT                           **
C*     VT       TIP VELOCITY                                          **
C*     DL       DISK LOADING
C*     W        WEIGHT AS CALCULATED FROM POWER EQUATION              **
C*     WE       USEFUL LOAD PLUS EMPTY WEIGHT                         **
C*     PA       POWER AVAILABLE IN HORSEPOWER                         **
C*                                                                    **
C****                                                              *****
C*     DL3 EQUALS THE DISK LOADING FOR CLR=.3
C*     DL4 EQUALS THE DISK LOADING FOR CLR=.4
C*     DL5 EQUALS THE DISK LOADING FOR CLR=.5
C*     DL6 EQUALS THE DISK LOADING FOR CLR=.6
C*     DL7 EQUALS THE DISK LOADING FOR CLR=.7
C*     W3 EQUALS THE WEIGHT FOR CLR=.3
C*     W4 EQUALS THE WEIGHT FOR CLR=.4
C*     W5 EQUALS THE WEIGHT FOR CLR=.5
C*     W6 EQUALS THE WEIGHT FOR CLR=.6
C*     W7 EQUALS THE WEIGHT FOR CLR=.7
C*     WVT1 EQUALS WEIGHTS AT VT=600
C*     WVT2 EQUALS WEIGHTS AT VT=625
C*     WVT3 EQUALS WEIGHTS AT VT=650
C*     WVT4 EQUALS WEIGHTS AT VT=675
C*     WVT5 EQUALS WEIGHTS AT VT=700
C*     DVT1 EQUALS THE CORRESPONDING DISK LOADING AT VT=600
C*     DVT2 EQUALS THE CORRESPONDING DISK LOADING AT VT=625
C*     DVT3 EQUALS THE CORRESPONDING DISK LOADING AT VT=650
C*     DVT4 EQUALS THE CORRESPONDING DISK LOADING AT VT=675
C*     DVT5 EQUALS THE CORRESPONDING DISK LOADING AT VT=700
C***********************************************************************
      REAL*4  DL3(5),DL4(5),DL5(5),DL6(5),DL7(5),W3(5),W4(5),
     *W5(5),W6(5),W7(5),WVT1(5),WVT2(5),WVT3(5),WVT4(5),
     *WVT5(5),DVT1(5),DVT2(5),DVT3(5),DVT4(5),DVT5(5)
C
C---- DEFINE DATA  -----------------------------------------------------
      DATA DL3/2.06,2.07,2.07,2.07,2.05/
      DATA W3/2505.,2478.2,2455.46,2433.85,2418.25/
      DATA DL4/2.42,2.44,2.46,2.47,2.47/
      DATA W4/2467.17,2442.95,2419.62,2399.72,2382.99/
      DATA DL5/2.63,2.65,2.67,2.69,2.69/
      DATA W5/2440.72,2419.51,2399.00,2379.13,2364.65/
      DATA DL6/2.74,2.77,2.79,2.81,2.81/
      DATA W6/2424.68,2402.48,2383.58,2365.10,2352./
      DATA DL7/2.80,2.83,2.85,2.86,2.87/
      DATA W7/2411.92,2390.72,2372.50,2357.35,2342.25/
      DATA WVT1/2505.,2467.17,2440.72,2424.67,2411.92/
      DATA WVT2/2478.2,2442.95,2419.51,2402.53,2390.72/
      DATA WVT3/2455.46,2419.62,2399.,2383.58,2372.5/
      DATA WVT4/2433.85,2399.72,2379.13,2365.1,2357.35/
      DATA WVT5/2418.25,2382.99,2364.65,2352.,2342.25/
      DATA DVT1/2.06,2.42,2.63,2.74,2.80/
      DATA DVT2/2.07,2.44,2.65,2.77,2.83/
      DATA DVT3/2.07,2.46,2.67,2.79,2.85/
      DATA DVT4/2.07,2.47,2.69,2.81,2.86/
      DATA DVT5/2.05,2.47,2.69,2.81,2.87/
C
C
```

```
C---- CALL DISSPLA ROUTINES FOR PLOT ----------------------------------
C
      CALL TEK618
      CALL MEDEUF
      CALL RESET (3HALL)
      CALL HWSCAL ('SCREEN')
      CALL PAGE (12.0, 9.5)
      CALL GRACE (0.0)
      CALL PHYSOR (1.0,1.2)
      CALL AREA2D (10.0,6.5)
      CALL FRAME
      CALL SWISSL
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STAND')
      CALL INTAXS
      CALL YTICKS (5)
      CALL XTICKS (5)
      CALL SHDCHR (.90,1,.015,1)
      CALL HEIGHT (.16)
      CALL XNAME (' (D)ISK (L)OADING$',100)
      CALL YNAME (' (G)ROSS (W)EIGHT ((LBS))$',100)
      CALL HEIGHT (.290)
      CALL HEADIN (' (H)ELICOPTER (C)ARPET (P)LOTS$',
     1            100,1.0,1)
      CALL HEIGHT (.20)
      CALL GRAF (2.0,.1,3.0,2300.,50.,2550.)
      IYGRID=5
      CALL THKCRV (.018)
      CALL PARA3
      CALL LEGLIN
      CALL CURVE (DL3,W3,5,0)
      CALL CURVE (DL4,W4,5,0)
      CALL CURVE (DL5,W5,5,0)
      CALL CURVE (DL6,W6,5,0)
      CALL CURVE (DL7,W7,5,0)
      CALL DASH
      CALL CURVE (DVT1,WVT1,5,0)
      CALL CURVE (DVT2,WVT2,5,0)
      CALL CURVE (DVT3,WVT3,5,0)
      CALL CURVE (DVT4,WVT4,5,0)
      CALL CURVE (DVT5,WVT5,5,0)
      CALL THKCRV (.030)
C     CALL BLREC (4.2,4.65,1.6,1.35,1)
C     CALL GRID (1,IYGRID)
C     CALL BLOFF (1)
C     MAXLIN=LINEST(IPAK1,300,20)
C     CALL HEIGHT (.12)
C     CALL LINESP (2.0)
C     CALL LINES (' (W)EIGHTS$',IPAK1,1)
C     CALL LINES (' (I)NDUCED$',IPAK1,2)
C     CALL LINES (' (P)ROFILES$',IPAK1,3)
C     CALL LINES (' (P)ARASITES$',IPAK1,4)
C     CALL MYLEGN (' (P)OWER (C)URVES',16)
C     CALL LEGEND (IPAK1,4,4.43,4.8)
      CALL DONEPL
      STOP
C     FORMAT STATEMENTS
C70   FORMAT (5(2X,F10.3))
C71   FORMAT (6(2X,F10.3))
      END
```

```
C***********************************************************************
C***********************************************************************
C**********      GRAPHICAL HELICOPTER DESIGN PROGRAM            **********
C*********            ASPECT RATIO BOUNDARY                      ********
C********        LOCI OF HOVER AND USEFUL-LOAD SOLUTIONS          ********
C********              CARPET PLOT NUMBER 3                        ********
C********                 BY AL HANSEN                              ********
C********                                                           ********
C********     THIS PROGRAM IS DESIGNED TO GRAPHICALLY DETERMINE     ********
C********       THE ASPECT RATIO BOUNDARY REQUIREMENTS FOR          ********
C********       A ROTOR SYSTEM USING PREVIOUSLY GENERATED DATA      ********
C**********                                                      **********
C***********************************************************************
C***********************************************************************
C****                                                               *****
C**                           NOMENCLATURE                            ***
C*                                                                     **
C*    VARIABLES:                                                       **
C*                                                                     **
C*    CLR      DESIGN MEAN LIFT COEFFICENT                             **
C*    VT       TIP VELOCITY                                            **
C*    DL       DISK LOADING
C*    AR       ASPECT RATIO. HISTORICALLLY ASSUMED TO BE LESS THAN 21  **
C*                                                                     **
C****                                                               *****
C*    DVT1 EQUALS THE CORRESPONDING DISK LOADING AT VT=600
C*    DVT2 EQUALS THE CORRESPONDING DISK LOADING AT VT=625
C*    DVT3 EQUALS THE CORRESPONDING DISK LOADING AT VT=650
C*    DVT4 EQUALS THE CORRESPONDING DISK LOADING AT VT=675
C*    DVT5 EQUALS THE CORRESPONDING DISK LOADING AT VT=700
C*    C600 EQUALS THE LIFT COEF AT VT=600
C*    C625 EQUALS THE LIFT COEF AT VT=625
C*    C650 EQUALS THE LIFT COEF AT VT=650
C*    C675 EQUALS THE LIFT COEF AT VT=675
C*    C700 EQUALS THE LIFT COEF AT VT=700
C***********************************************************************
      REAL*4 CLR(5),DL(10),C600(10),C625(10),C650(10),
     *C675(10),C700(10),
     *DVT1(5),DVT2(5),DVT3(5),DVT4(5),DVT5(5)
C
C---- DEFINE DATA  -----------------------------------------------------
      DATA DVT1/2.06,2.42,2.63,2.74,2.80/
      DATA DVT2/2.07,2.44,2.65,2.77,2.83/
      DATA DVT3/2.07,2.46,2.67,2.79,2.85/
      DATA DVT4/2.07,2.47,2.69,2.81,2.86/
      DATA DVT5/2.05,2.48,2.70,2.82,2.87/
      DATA CLR/.3,.4,.5,.6,.7/
      DATA DL/2.,2.1,2.2,2.3,2.4,2.5,2.6,2.7,2.8,2.9/
      DATA C600/.47,.49,.51,.53,.55,.57,.59,.61,.63,.65/
      DATA C625/.43,.45,.47,.49,.51,.53,.55,.57,.59,.61/
      DATA C650/.39,.41,.43,.45,.47,.49,.51,.53,.55,.57/
      DATA C675/.35,.37,.39,.41,.43,.45,.47,.49,.51,.53/
      DATA C700/.31,.33,.35,.37,.39,.41,.43,.45,.47,.49/
C
C
C---- CALL DISSPLA ROUTINES FOR PLOT ------------------------------------
C
      CALL TEK618
      CALL MEDEUF
      CALL RESET (3HALL)
      CALL HWSCAL ('SCREEN')
      CALL PAGE (12.0, 9.5)
      CALL GRACE (0.0)
      CALL PHYSOR (1.0,1.2)
      CALL AREA2D (10.0,6.5)
      CALL FRAME
      CALL SWISSL
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STAND')
      CALL INTAXS
      CALL SHDCHR (.90,1,.015,1)
      CALL HEIGHT (.16)
      CALL XNAME ('(D)ISK (L)OADING$',100)
      CALL YNAME ('(C)OEFFICENT OF (L)IFTS$',100)
      CALL HEIGHT (.290)
      CALL MESSAG ('(H)ELICOPTER (C)ARPET (P)LOTS$',
```

```
1                 100.3.25,7.55)
 CALL HEIGHT (.20)
 CALL GRAF (2.0,.1,2.9,.2,.05,.8)
 IYGRID=5
 CALL THKCRV (.018)
 CALL PARA3
 CALL LEGLIN
 CALL CURVE (DI,C600,10,0)
 CALL CURVE (DI,C625,10,0)
 CALL CURVE (DI,C650,10,0)
 CALL CURVE (DI,C675,10,0)
 CALL CURVE (DI,C700,10,0)
 CALL DASH
 CALL CURVE (DVT1,CIR,5,0)
 CALL CURVE (DVT2,CIR,5,0)
 CALL CURVE (DVT3,CIR,5,0)
 CALL CURVE (DVT4,CIR,5,0)
 CALL CURVE (DVT5,CIR,5,0)
 CALL THKCRV (.030)
 CALL DONEPL
 STOP
 END
```

```
C****************************************************************
C****************************************************************
C**********      GRAPHICAL HELICOPTER DESIGN PROGRAM      **********
C*********          FAMILY OF SOLUTIONS                    *********
C*********          CARPET PLOT NUMBER 4                   *********
C*********             BY AL HANSEN                        *********
C*********                                                 *********
C*********  THIS PROGRAM IS DESIGNED TO ILLUSTRATE THE FAMILY *******
C*********    OF SOLUTIONS FOR HOVER AND USEFUL LOAD       *********
C*********    REQUIREMENTS OF A TEETERING ROTOR SYSTEM     *********
C*********    WITH ROTOR DIAMETER AND MAX GROSS BOUNDRIES. *********
C*********         OBSERVATION CLASS HELICOPTER            *********
C**********                                               **********
C****************************************************************
C****************************************************************
C****                                                        *****
C**                         NOMENCLATURE                       ***
C*                                                              **
C*    VARIABLES:                                                **
C*                                                              **
C*    CLR      DESIGN MEAN LIFT COEFFICENT                      **
C*    VT       TIP VELOCITY                                     **
C*    DL       DISK LOADING
C*    W        WEIGHT AS CALCULATED FROM POWER EQUATION         **
C*    WB       USEFUL LOAD PLUS EMPTY WEIGHT                    **
C*    PA       POWER AVAILABLE IN HORSEPOWER                    **
C*                                                              **
C****                                                        *****
C*    DL3 EQUALS THE DISK LOADING FOR CLR=.3
C*    DL4 EQUALS THE DISK LOADING FOR CLR=.4
C*    DL5 EQUALS THE DISK LOADING FOR CLR=.5
C*    DL6 EQUALS THE DISK LOADING FOR CLR=.6
C*    DL7 EQUALS THE DISK LOADING FOR CLR=.7
C*    W3 EQUALS THE WEIGHT FOR CLR=.3
C*    W4 EQUALS THE WEIGHT FOR CLR=.4
C*    W5 EQUALS THE WEIGHT FOR CLR=.5
C*    W6 EQUALS THE WEIGHT FOR CLR=.6
C*    W7 EQUALS THE WEIGHT FOR CLR=.7
C*    WVT1 EQUALS WEIGHTS AT VT=600
C*    WVT2 EQUALS WEIGHTS AT VT=625
C*    WVT3 EQUALS WEIGHTS AT VT=650
C*    WVT4 EQUALS WEIGHTS AT VT=675
C*    WVT5 EQUALS WEIGHTS AT VT=700
C*    DVT1 EQUALS THE CORRESPONDING DISK LOADING AT VT=600
C*    DVT2 EQUALS THE CORRESPONDING DISK LOADING AT VT=625
C*    DVT3 EQUALS THE CORRESPONDING DISK LOADING AT VT=650
C*    DVT4 EQUALS THE CORRESPONDING DISK LOADING AT VT=675
C*    DVT5 EQUALS THE CORRESPONDING DISK LOADING AT VT=700
C*    RDB ROTOR DISK BOUNDARY
C*    WMG MAX GROSS WEIGHT BOUNDARY
C****************************************************************
      REAL*4 DL3(5),DL4(5),DL5(5),DL6(5),DL7(5),W3(5),W4(5),RDB(2),
     *W5(5),W6(5),W7(5),WVT1(5),WVT2(5),WVT3(5),WVT4(5),WMG(2),
     *WVT5(5),DVT1(5),DVT2(5),DVT3(5),DVT4(5),DVT5(5),D1(2),D2(2)
C
C---- DEFINE DATA -----------------------------------------------
      DATA DL3/2.06,2.07,2.07,2.07,2.05/
      DATA W3/2505.,2478.2,2455.46,2433.85,2418.25/
      DATA DL4/2.42,2.44,2.46,2.47,2.47/
      DATA W4/2467.17,2442.95,2419.62,2399.72,2382.99/
      DATA DL5/2.63,2.65,2.67,2.69,2.69/
      DATA W5/2440.72,2419.51,2399.00,2379.13,2364.65/
      DATA DL6/2.74,2.77,2.79,2.81,2.81/
      DATA W6/2424.68,2402.48,2383.58,2365.10,2352./
      DATA DL7/2.80,2.83,2.85,2.86,2.87/
      DATA W7/2411.92,2390.72,2372.50,2357.35,2342.25/
      DATA WVT1/2505.,2467.17,2440.72,2424.67,2411.92/
      DATA WVT2/2478.2,2442.95,2419.51,2402.53,2390.72/
      DATA WVT3/2455.46,2419.62,2399.,2383.58,2372.5/
      DATA WVT4/2433.85,2399.72,2379.13,2365.1,2357.35/
      DATA WVT5/2418.25,2382.99,2364.65,2352.,2342.25/
      DATA DVT1/2.06,2.42,2.63,2.74,2.80/
      DATA DVT2/2.07,2.44,2.65,2.77,2.83/
      DATA DVT3/2.07,2.46,2.67,2.79,2.85/
      DATA DVT4/2.07,2.47,2.69,2.81,2.86/
      DATA DVT5/2.05,2.47,2.69,2.81,2.87/
```

```
      DATA D1/2.52,2.9/
      DATA WMG/2450.,2450./
      DATA D2/2.36,2.52/
      DATA RDB/2300.,2450./
C
C
C---- CALL DISSPLA ROUTINES FOR PLOT -----------------------------------
C
      CALL TEK618
      CALL MEDEUF
      CALL RESET (3HALL)
      CALL HWSCAL ('SCREEN')
      CALL PAGE (12.0, 9.5)
      CALL GRACE (0.0)
      CALL PHYSOR (1.0,1.2)
      CALL AREA2D (10.,6.5)
      CALL FRAME
      CALL SWISSL
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STAND')
      CALL INTAXS
      CALL YTICKS (5)
      CALL XTICKS (5)
      CALL SHDCHR (.90,1,.015,1)
      CALL HEIGHT (.16)
      CALL XNAME ('(D)ISK (L)OADING$',100)
      CALL YNAME ('(G)ROSS (W)EIGHT ((LBS))$',100)
      CALL HEIGHT (.290)
      CALL HEADIN ('(H)ELICOPTER (C)ARPET (P)LOTS$',
     1             100,1.0,1)
      CALL HEIGHT (.20)
      CALL GRAF (2.0,.1,3.0,2300.,50.,2550.)
      IYGRID=5
      CALL THKCRV (.018)
      CALL PARA3
      CALL LEGLIN
      CALL CURVE (DL3,W3,5,0)
      CALL CURVE (DL4,W4,5,0)
      CALL CURVE (DL5,W5,5,0)
      CALL CURVE (DL6,W6,5,0)
      CALL CURVE (DL7,W7,5,0)
      CALL DASH
      CALL CURVE (DVT1,WVT1,5,0)
      CALL CURVE (DVT2,WVT2,5,0)
      CALL CURVE (DVT3,WVT3,5,0)
      CALL CURVE (DVT4,WVT4,5,0)
      CALL CURVE (DVT5,WVT5,5,0)
      CALL THKCRV (.030)
      CALL CHNDOT
      CALL CURVE (D1,WMG,2,0)
      CALL CURVE (D2,RDB,2,0)
      CALL DONEPL
      STOP
      END
```

```
C***************************************************************************
C***************************************************************************
C***********        GRAPHICAL HELICOPTER DESIGN PROGRAM            **********
C*********                FAMILY OF SOLUTIONS                       *********
C*********                CARPET PLOT NUMBER 5                       ********
C*********                    BY AL HANSEN                           ********
C*********                                                           ********
C*********     THIS PROGRAM IS DESIGNED TO ILLUSTRATE THE FAMILY     ********
C*********       OF SOLUTIONS FOR HOVER AND USEFUL LOAD              ********
C*********       REQUIREMENTS OF A TEETERING ROTOR SYSTEM            ********
C*********       WITH ROTOR DIAMETER, MAX GROSS WEIGHT AND           ********
C*********              ASPECT RATIO BOUNDARIES.                     ********
C*********              OBSERVATION CLASS HELICOPTER                 ********
C***********                                                       **********
C***************************************************************************
C***************************************************************************
C****                                                                  *****
C**                          NOMENCLATURE                               ***
C*                                                                       **
C*     VARIABLES:                                                        **
C*                                                                       **
C*     CLR       DESIGN MEAN LIFT COEFFICENT                             **
C*     VT        TIP VELOCITY                                            **
C*     DL        DISK LOADING
C*     W         WEIGHT AS CALCULATED FROM POWER EQUATION                **
C*     WE        USEFUL LOAD PLUS EMPTY WEIGHT                           **
C*     PA        POWER AVAILABLE IN HORSEPOWER                           **
C*                                                                       **
C****                                                                  *****
C*     DL3 EQUALS THE DISK LOADING FOR CLR=.3
C*     DL4 EQUALS THE DISK LOADING FOR CLR=.4
C*     DL5 EQUALS THE DISK LOADING FOR CLR=.5
C*     DL6 EQUALS THE DISK LOADING FOR CLR=.6
C*     DL7 EQUALS THE DISK LOADING FOR CLR=.7
C*     W3 EQUALS THE WEIGHT FOR CLR=.3
C*     W4 EQUALS THE WEIGHT FOR CLR=.4
C*     W5 EQUALS THE WEIGHT FOR CLR=.5
C*     W6 EQUALS THE WEIGHT FOR CLR=.6
C*     W7 EQUALS THE WEIGHT FOR CLR=.7
C*     WVT1 EQUALS WEIGHTS AT VT=600
C*     WVT2 EQUALS WEIGHTS AT VT=625
C*     WVT3 EQUALS WEIGHTS AT VT=650
C*     WVT4 EQUALS WEIGHTS AT VT=675
C*     WVT5 EQUALS WEIGHTS AT VT=700
C*     DVT1 EQUALS THE CORRESPONDING DISK LOADING AT VT=600
C*     DVT2 EQUALS THE CORRESPONDING DISK LOADING AT VT=625
C*     DVT3 EQUALS THE CORRESPONDING DISK LOADING AT VT=650
C*     DVT4 EQUALS THE CORRESPONDING DISK LOADING AT VT=675
C*     DVT5 EQUALS THE CORRESPONDING DISK LOADING AT VT=700
C*     RDB ROTOR DISK BOUNDARY
C*     WMG MAX GROSS WEIGHT BOUNDARY
C*     AR WEIGHTS FOR THE ASPECT RATIO BOUNDARY
C*     D3 DISK LOADING CORRESPONDING TO THE ASPECT RATIO WEIGHTS
C***************************************************************************
      REAL*4 DL3(5),DL4(5),DL5(5),DL6(5),DL7(5),W3(5),W4(5),RDB(2),
     *W5(5),W6(5),W7(5),WVT1(5),WVT2(5),WVT3(5),WVT4(5),WMG(2),
     *WVT5(5),DVT1(5),DVT2(5),DVT3(5),DVT4(5),DVT5(5),D1(2),D2(2),
     *D3(5),AR(5)
C
C---- DEFINE DATA  ---------------------------------------------------------
      DATA DL3/2.06,2.07,2.07,2.07,2.05/
      DATA W3/2505.,2478.2,2455.46,2433.85,2418.25/
      DATA DL4/2.42,2.44,2.46,2.47,2.47/
      DATA W4/2467.17,2442.95,2419.62,2399.72,2382.99/
      DATA DL5/2.63,2.65,2.67,2.69,2.69/
      DATA W5/2440.72,2419.51,2399.00,2379.13,2364.65/
      DATA DL6/2.74,2.77,2.79,2.81,2.81/
      DATA W6/2424.68,2402.48,2383.58,2365.10,2352./
      DATA DL7/2.80,2.83,2.85,2.86,2.87/
      DATA W7/2411.92,2390.72,2372.50,2357.35,2342.25/
      DATA WVT1/2505.,2467.17,2440.72,2424.67,2411.92/
      DATA WVT2/2478.2,2442.95,2419.51,2402.53,2390.72/
      DATA WVT3/2455.46,2419.62,2399.,2383.58,2372.5/
      DATA WVT4/2433.85,2399.72,2379.13,2365.1,2357.35/
      DATA WVT5/2418.25,2382.99,2364.65,2352.,2342.25/
      DATA DVT1/2.06,2.42,2.63,2.74,2.80/
```

```
      DATA DVT2/2.07,2.44,2.65,2.77,2.83/
      DATA DVT3/2.07,2.46,2.67,2.79,2.85/
      DATA DVT4/2.07,2.47,2.69,2.81,2.86/
      DATA DVT5/2.05,2.47,2.69,2.81,2.87/
      DATA D1/2.52,2.9/
      DATA WMG/2450.,2450./
      DATA D2/2.36,2.52/
      DATA RDB/2300.,2450./
      DATA AR/2374.461,2390.,2405.,2420.,2450./
      DATA D3/2.44,2.65,2.715,2.745,2.78/
C
C
C---- CALL DISSPLA ROUTINES FOR PLOT ----------------------------------
C
      CALL TEK618
      CALL MEDEUF
      CALL RESET (3HALL)
      CALL HWSCAL ('SCREEN')
      CALL PAGE (12.0, 9.5)
      CALL GRACE (0.0)
      CALL PHYSOR (1.0,1.2)
      CALL AREA2D (10.,6.5)
      CALL FRAME
      CALL SWISSL
      CALL BASALF ('L/CSTD')
      CALL MIXALF ('STAND')
      CALL INTAXS
      CALL YTICKS (5)
      CALL XTICKS (5)
      CALL SHDCHR (.90,1,.015,1)
      CALL HEIGHT (.16)
      CALL XNAME ('(D)ISK (L)OADING$',100)
      CALL YNAME ('(G)ROSS (W)EIGHT ((LBS))$',100)
      CALL HEIGHT (.290)
      CALL HEADIN ('(H)ELICOPTER (C)ARPET (P)LOTS$',
     1            100,1.0,1)
      CALL HEIGHT (.20)
      CALL GRAF (2.0,.1,3.0,2300.,50.,2550.)
      IYGRID=5
      CALL THKCRV (.018)
      CALL PARA3
      CALL LEGLIN
      CALL CURVE (DL3,W3,5,0)
      CALL CURVE (DL4,W4,5,0)
      CALL CURVE (DL5,W5,5,0)
      CALL CURVE (DL6,W6,5,0)
      CALL CURVE (DL7,W7,5,0)
      CALL DASH
      CALL CURVE (DVT1,WVT1,5,0)
      CALL CURVE (DVT2,WVT2,5,0)
      CALL CURVE (DVT3,WVT3,5,0)
      CALL CURVE (DVT4,WVT4,5,0)
      CALL CURVE (DVT5,WVT5,5,0)
      CALL THKCRV (.030)
      CALL CHNDOT
      CALL CURVE (D1,WMG,2,0)
      CALL CURVE (D2,RDB,2,0)
      CALL CURVE (D3,AR,5,0)
      CALL DONEPL
      STOP
      END
```

```
C  THIS PROGRAM IS DESIGN TO GENERATE THE DATA FOR THE GRAPHICAL
C  SOLUTION OF THE WEIGHT AND THE USEFUL LOAD EQUATION.  THIS IS THE
C  FIRST STEP IN A CARPET PLOT HELICOPTER DESIGN PARAMETRIC OPTIMIZATION
C
C      ASSUMPTIONS:
C                 1> ENGINESPECIFIED
C VARIABLE OPTIONS
C
      REAL*4 CLR,PA,DL,K1,K2,K3,K4,K5,R,S,A,P,W(10),WB(10)
      INTEGER VT,D,I,CL
C
C--------------------------------------------------------------------------
      CALL FRTCMS ('FILEDEF ','02      ','DISK    ','CRPT1',
     >'DATA    ','A       ')
C--------------------------------------------------------------------------
C--------------------------------------------------------------------------
      CALL FRTCMS ('FILEDEF ','03      ','DISK    ','CRPT2',
     >'DATA    ','A       ')
C--------------------------------------------------------------------------
C
C     CLR= DESIGN MEAN LIFT COEFFICIENT
      DO 90 CL=3,7
      CLR=CL*(0.1)
      WRITE(2,10)CLR
C     PA= POWER AVAILABLE HP
      PA=206
C     DL= DISK LOADING
C     VT= TIP VELOCITY FT/SEC
C
C     CONSTANTS BASED ON CLR
C
      K1=(0.9583)/CLR*(1+1.8078*CLR**2)
      K2=PA*10**5/K1
      K3=(0.00025929)/CLR*(1+1.8078*CLR**2)
      K4=553480.0/K1
      K5=3695.7/K1
      DO 100  D=200,300
       DL=D*(0.01)
       I=0
         DO 110  VT=600,700,25
C
C        ARRAY INCREMENTER
         I=I+1
C        WEIGHT EQUATION
C
      W(I)=(K2*(1-(411.51*DL**.75)/(VT**1.5)*(1+K3*VT/DL**.5)**.5)-K4)
     1/(VT+K5*DL**.5)
C
C     CALCULATION OF WE DATA
C
      A=W(I)/DL
      R=(A/3.14)**.5
      P=A**.5/VT
      S=(6.*DL)/(0.0023679*CLR*VT**2)
C
C     ASSUMING A TEETERING SYSTEM
C
      WE(I)=1717.9+1221.*P**.863+266.*P**.7+17449./VT**1.14
     1+2.886*A**.5*P**.57+.191*W(I)**.916+.0294*W(I)**.99
     2+35.15*(W(I)/VT)*(A**.185)*S**.33+.0088*W(I)*A**.21
C         WRITE (5,20)VT
C         WRITE(5,30)R
 110     CONTINUE
          WRITE (2,31)DL,W(1),WE(1),W(2),WE(2)
          WRITE (3,31) DL,W(3),WB(3),W(4),WB(4),W(5),WB(5)
 100  CONTINUE
  90  CONTINUE
C     FORMAT STATEMENTS
 10   FORMAT ('1','CLR=',1F10.4///)
 31   FORMAT (6(2X,F10.3))
      STOP
      END
```

```
C************************************************************************
C************************************************************************
C  THIS PROGRAM IS DESIGN TO OBTAIN THE GROSS WEIGHT FROM THE          *
C  ASPECT RATIO GRAPH INTERSECTION POINT DATA. IN ORDER TO GRAPH       *
C  THE ASPECT RATIO BOUNDARY ON THE MAIN CARPET PLOT A                 *
C  CORRESPONDING WEIGHT MUST BE OBTAINED. THIS PROGRAM UTILIZES        *
C  THE WEIGHT ESTIMATION FORMULATION FROM THE CARPET PROGRAM.          *
C************************************************************************
C************************************************************************
C  ASSUMPTIONS:                                                        *
C                    1> ENGINESPECIFIED                                *
C************************************************************************
C************************************************************************
C VARIABLE OPTIONS
      REAL*4 VT(5),DL(5),CLR(5),W(5)
      DATA CLR/.625,.575,.535,.460,.42/
      DATA VT/600.,625.,650.,675.,700./
      DATA DL/2.75,2.75,2.72,2.67,2.53/
C-------------------------------------------------------------------------
      CALL FRTCMS ('FILEDEF ','03      ','DISK    ','CRPTAR',
     >'DATA    ','A       ')
C-------------------------------------------------------------------------
C
      DO 90 L=1,5
      WRITE(3,10)CLR(I)
      WRITE(3,20)VT(I)
      WRITE(3,30)DL(I)
C     PA= POWER AVAILABLE HP
      PA=206
C     DL= DISK LOADING
C     VT= TIP VELOCITY FT/SEC
C
C     CONSTANTS BASED ON CLR
C
      K1=(0.9583)/CLR(L)*(1+1.8078*CLR(L)**2)
      K2=PA*10**5/K1
      K3=(0.00025929)/CLR(L)*(1+1.8078*CLR(L)**2)
      K4=553480.0/K1
      K5=3695.7/K1
C        WEIGHT EQUATION
C
      W(L)=(K2*(1-(411.51*DL(L)**.75)/(VT(L)**1.5)*
     1(1+K3*VT(L)/DL(L)**.5)**.5)-K4)/(VT(L)+K5*(DL(L)**.5))
      WRITE (3,31)W(I)
 90   CONTINUE
C     FORMAT STATEMENTS
 10   FORMAT ('1','CLR=',1F10.4///)
 20   FORMAT (2X,'VT=',1F10.4///)
 30   FORMAT (2X,'DL=',1F10.4///)
 31   FORMAT (2X,F10.3)
      STOP
      END
```

APPENDIX D. PROGRAMS TO ACCESS HESCOMP

This section contains the control language programs needed to access HESCOMP on the IBM main-frame computer.

```
C************************************************************************
C************************************************************************
C******                                                           *******
C**   NOTE!!!! THE PROGRAM INPUT CARDS (DATA LINES) DO NOT HAVE TO   ***
C**     BE IN NUMERICAL ORDER. ERASE THESE COMMENT LINES IF RUNNING  ***
C**    PROGRAM                                                       ***
C******                                                           *******
C************************************************************************
C************************************************************************
//HESCOMP1 JOB (2399,5555),'AL HANSEN',CLASS=B
//*MAIN ORG=NPGVM1.2399P,LINES=(10)
//   EXEC HESCOMP
//SYSIN DD *
77777
      SAMPLE CASE NO. 1    RUN 1               1/26/84
120150.             0.            0.            2.             0.
120610.
122310.905
130151.761          0.159         0.            0.032          950.
130651100.          1856.         2000.         2000.          8.
13115870.           1200.         1400.         1600.          1800.
131652000.          2200.         2600.         5.             0.
132140.2            0.4           0.6           0.8
132650.             0.            0.            0.             0.
13325.163           .1676         .1613         .2041          .236
13385.335           .3444         .3725         .4194          .4851
13445.544           .5592         .6049         .6811          .7877
13505.770           .7916         .8562         .964           1.115
135651.0            1.028         1.112         1.252          1.448
136251.2            1.2336        1.3344        1.5024         1.7376
136851.55           1.5934        1.7236        1.9406         2.2444
137458.             870.          1200.         1400.          1600.
137951800.          2000.         2200.         2600.          5.
138450.             0.2           0.4           0.6            0.8
13905.065           .0651         .0653         .067           .071
13965.115           .116          .118          .128           .14
14025.180           .181          .19           .208           .227
14085.26            .261          .273          .295           .325
14145.342           .347          .362          .389           .425
14205.425           .435          .451          .486           .517
14265.5             .511          .53           .56            .61
14325.626           .631          .66           .718           .78
143843.             870.          1600.         2600.
144743.             0.            0.4           0.8
145430.26           0.271         0.29
146030.82           0.84          0.90
146631.09           1.118         1.165
150258.             870.          1200.         1400.          1600.
150751800.          2000.         2200.         2600.          5.
151250.             0.2           0.4           0.6            0.8
151850.26           0.265         0.271         0.28           0.29
152450.52           0.527         0.54          0.56           0.59
153050.68           0.69          0.705         0.73           0.76
153650.82           0.824         0.84          0.868          0.90
154250.92           0.93          0.95          0.98           1.02
154851.0            1.002         1.02          1.05           1.09
155451.052          1.055         1.07          1.10           1.131
156051.09           1.10          1.118         1.135          1.165
66666
120150.             0.            0.            2.             0.
120610.
122320.905          0.
130151.761          0.159         0.            0.032          950.
130651100.          1856.         2000.         2000.          8.
13115870.           1200.         1400.         1600.          1800.
131652000.          2200.         2600.         5.             0.
132140.2            0.4           0.6           0.8
132650.             0.            0.            0.             0.
13325.163           .1676         .1613         .2041          .236
13385.335           .3444         .3725         .4194          .4851
13445.544           .5592         .6049         .6811          .7877
13505.770           .7916         .8562         .964           1.115
135651.0            1.028         1.112         1.252          1.448
136251.2            1.2336        1.3344        1.5024         1.7376
136851.55           1.5934        1.7236        1.9406         2.2444
137458.             870.          1200.         1400.          1600.
```

```
024622.             1.105
024851.             900.        10.         .075        .97
025310.
02542.82            .80
02572140.           3.
026114.0
026240.             0.2         0.4         0.8
02724.85            .83         .80         .78
031241130.          .555        .75         1.0
032310.0
032711.02
032821.464COCOCE 066.28
033017.0
033150.0            0.2         0.4         0.6         0.8
033621.0            1.4
03355.006           .0062       .007        .008        .0095
03442.012           .020
260232200.          450.        2000.
26053100.           0.          0.
260650.             0.          0.          0.          0.
2613525.            25.         25.         0.          0.
2618430.            .18         25.         0.
26225125.           2.08        .04         .8          0.
262751.             0.          2.06        2.0         24.1
263251.0            .75         1.0         .75         0.
2637544.            2.2         61.         .286        1.15
2642514.2           14.2        1.0         1.0         250.
264753.             250.        250.        1.          .11
26522.17            .17
265451.0            1.0         1.0         1.0         1.0
265551.0            1.0         1.0         1.0         1.0
266451.0            1.0         1.0         1.0         1.0
266951.0            1.0         1.0         1.0         1.0
034753.0            3.0         0.0         0.5         1.0
035430.0            0.5         1.0
036131.0            1.0         1.0
036831.0            1.0         1.0
037531.0            1.0         1.0
040110.
04111.0333
042110.
043111.0
044111.105
046121.0            1.0
048120.             0.
050120.             0.
051120.             0.
052121.06           1.06
05312.02            .02
054121.105          1.105
05512.1             .2
057121.             1.
059120.             0.
06012.3             .4
061120.             0.
06212500.           500.
063122.             2.
06412500C.          3000.
065121.105          1.105
066126.             6.
067121.105          1.105
068121.             1.
069120.             0.
070121.             1.
072132.             4.          4.
07311170.
074130.             0.          0.
07513.5             .5          .5
076130.             0.          0.
0771315.            15.         15.
078132.             2.          2.
0791360.            150.        300.
080131.105          1.105       1.105
081130.             0.          0.
082131.105          1.105       1.105
083130.             0.          0.
```

```
137551800.            2000.             2200.             2600.             5.
138450.               0.2               0.4               0.6               0.8
13905.065             .0651             .0653             .067              .071
13965.115             .116              .116              .128              .14
14025.180             .181              .19               .208              .227
14085.26              .261              .273              .295              .325
14145.342             .347              .362              .389              .425
14205.425             .435              .451              .486              .517
14265.5               .511              .53               .56               .61
14325.626             .631              .66               .718              .78
143843.               870.              1600.             2600.
144743.               0.                0.4               0.8
145430.26             0.271             0.29
146030.82             0.84              0.90
146631.09             1.118             1.165
150258.               870.              1200.             1400.             1600.
150751800.            2000.             2200.             2600.             5.
151250.               0.2               0.4               0.6               0.8
151850.26             0.265             0.271             0.28              0.29
152450.52             0.527             0.54              0.56              0.59
153050.66             0.69              0.705             0.73              0.76
153650.82             0.824             0.84              0.868             0.90
154250.92             0.93              0.95              0.98              1.02
154851.0              1.002             1.02              1.05              1.09
155451.052            1.055             1.07              1.10              1.131
156051.09             1.10              1.118             1.135             1.165
66666
160123.0              -9.0
16035.0074918         -.028             .262              .276              2.45
16081.865
16055.0079059         2.82              .09               1.17              .00124
16142.758             .743
1616510.              0.                .004              .007              .009
16215.010             .011              .0115             .012              .0155
16265.022             1.018             1.065             1.154             1.233
163151.279            1.314             1.327             1.337             1.364
163611.357
000151.               1.                2.                0.                1.
000654.               4.                1.                1.                3.
001151.               2.                0.                1.                1.
001642.               2.                2.                0.
002252.               25000.            0.                0.                0.
002750.               .33               220.              220.              3.5
003251.0              0.0               1.05              1.0               2.0
003754.0              3.0               4.0               9.0               2.0
004258.0              6.0               3.0               4.0               60.
004711000.
010310.5
01055.20              .12               0.                .5                1.0
01105.2               .8                4.0               1.15              .12
01152.0162            .5
012050.0              0.0               7.0               6.5               1.3
012551.0              12.               0.                .55               5.
01302.3               1.1
01365.45              .15               .8                .85               .5
01415180.             .035              2.0               .078              0.1
01465.035             2.0               .078              0.                0.
01511.1
01525.4               .2                .5                .4                3.
017133.               1.                11.
017654.               -9.               .25               .075              .1
018157250.            .12               1.06              165.              3000.
0186543.2             .110              1.75              1.35              1.0
019131.53             0.                .85
020355.               -4.               .3                .075              690.
02085.17              .30               .75               1.00              .72
021331.00             1.0               1.05
021610.
021711.761
021932.0              2.0               1.0
02235.97              100.              1.0               1.0               4000.
022851.06             50.3              1.105             0.0               .95
023350.0              2.0               3000.             170.              43.2
023841.105            .75               .30               0.
024211.761
024511.0
```

```
08413.55            .60           .70
085130.             0.            0.
103120.             0.
10412.4             .4
105120.             0.
10612.05            .05
107121.105          1.105
10812.5             .25
109121.105          1.105
110120.0            0.0
11111.35
112120.0            0.0
113120.0            0.0
11611-1000.
11711.01
118111000.
119111.0
88888
99999
/*
//
```

APPENDIX E: HESCOMP INPUT AND OUTPUT EXAMPLES

This section contains samples of the IBM computer input and output.

```
                              H E S C O M P
         HELICCPTER SIZING & PERFORMANCE COMPUTER PROGRAM     E-

      THE FCILCWING IS A CARD BY CARD REPRODUCTION OF THE INPUTR THIS CASE

LOC.  CORRESICNDS TO LCCATICN NUMBER GIVEN ON INPUT SHEET
NUM   STANDS FCR THE NUMBEF CF SEQUENTIAL INPUT VALUES STARTINGC.  (MAX. =5)
VAL   EQUAIS VALUE FOR VARIAELE CCRRESPONDING TO LOC.
VAL1         VALUE               CCRRESPONDING TO LOC.+0001
VAL2         VALUE               CCRRESPONDING TO LOC.+0002
      ETC.

  LOC.        NUM         VAL              VAL1            VA       VAL3            VAL4

      NOTE : IN USING AUXIIIARY ENGINES ; AUXILIARY ENGINE CYCLLOCATIONS CAN BE CREATED
      EY PLACING A 66666 CARD IN FRONT AND BEHIND A STANDARD ENIE

  1201        5           .0               .0              .0       2.0000          .0
  1206        1           .0
  1223        1           .90500
  1301        5           1.7610           .15900          .0       .32000E-01      950.00
  1306        5           1100.0           1856.0          200      2000.0          8.0000
  1311        5           870.00           1200.0          140      1600.0          1800.0
  1316        5           2000.0           2200.0          260      5.0000          .0
  1321        4           .20000           .40000          .60      .80000
  1326        5           .0               .0              .0       .0              .0
  1332        5           .16300           .16700          .18      .20410          .23600
  1338        5           .33500           .34440          .37      .41940          .48510
  1344        5           .54400           .55920          .60      .68110          .78770
  1350        5           .77000           .79160          .85      .96400          1.1150
  1356        5           1.0000           1.0280          1.1      1.2520          1.4480
  1362        5           1.2000           1.2336          1.3      1.5024          1.7376
  1368        5           1.5500           1.5934          1.7      1.9406          2.2444
  1374        5           8.0000           870.00          120      1400.0          1600.0
  1379        5           1800.0           2000.0          220      2600.0          5.0000
  1384        5           .0               .20000          .40      .60000          .80000
  1390        5           .65000E-01       .65100E-01      .65      .67000E-01      .71000E-01
  1396        5           .11500           .11600          .11      .12800          .14000
  1402        5           .18000           .18100          .19      .20800          .22700
  1408        5           .26000           .26100          .27      .29500          .32500
  1414        5           .34200           .34700          .36      .38900          .42500
  1420        5           .42500           .43500          .45      .48600          .51700
  1426        5           .50000           .51100          .53      .56000          .61000
  1432        5           .62600           .63100          .66      .71800          .78000
  1438        4           3.0000           870.00          160      2600.0
  1447        4           3.0000           .0              .40      .80000
  1454        3           .26000           .27100          .29
  1460        3           .82000           .84000          .90
  1466        3           1.0900           1.1180          1.1
  1502        5           8.0000           870.00          120      1400.0          1600.0
  1507        5           1800.0           2000.0          220      2600.0          5.0000
  1512        5           .0               .20000          .40      .60000          .80000
  1518        5           .26000           .26500          .27      .28000          .29000
  1524        5           .52000           .52700          .54      .56000          .59000
  1530        5           .68000           .69000          .70      .73000          .76000
  1536        5           .82000           .82400          .84      .86800          .90000
  1542        5           .92000           .93000          .95      .98000          1.0200
  1548        5           1.0000           1.0020          1.0      1.0500          1.0900
  1554        5           1.0520           1.0550          1.0      1.1000          1.1310
  1560        5           1.0900           1.1000          1.1      1.1350          1.1650
  2201        5           .0               .0              .0       2.0000          .0
  2206        1           .0
```

```
2223   2   .90500       .0
2301   5   1.7610       .15900       .C     .32000E-01   950.00
2306   5   1100.0       1856.0       200    2000.0       8.0000
2311   5   870.00       1200.0       140    1600.0       1800.0
2316   5   2000.0       2200.0       260    5.0000       .0
2321   4   .20000       .40000       .60    .80000
2326   5   .0           .0           .0     .0           .0
2332   5   .16300       .16760       .18    .20410       .23600
2338   5   .33500       .34440       .37    .41940       .48510
2344   5   .54400       .55920       .60    .68110       .78770
2350   5   .77000       .79160       .85    .96400       1.1150
2356   5   1.0000       1.0280       1.1    1.2520       1.4480
2362   5   1.2000       1.2336       1.3    1.5024       1.7376
2368   5   1.5500       1.5934       1.7    1.7406       2.2444
2374   5   8.0000       870.00       120    1400.0       1600.0
2379   5   1800.0       2000.0       220    2600.0       5.0000
2384   5   .0           .20000       .40    .60000       .80000
2390   5   .65000E-01   .65100E-01   .65    .67000E-01   .71000E-01
2396   5   .11500       .11600       .11    .12800       .14000
2402   5   .18000       .18100       .19    .20800       .22700
2408   5   .26000       .26100       .27    .29500       .32500
2414   5   .34200       .34700       .36    .38900       .42500
2420   5   .42500       .43500       .45    .48600       .51700
2426   5   .50000       .51100       .53    .56000       .61000
2432   5   .62600       .63100       .66    .71800       .78000
2438   4   3.0000       870.00       160    2600.0
2447   4   3.0000       .0           .40    .80000
2454   3   .26000       .27100       .29
2460   3   .82000       .84000       .90
2466   3   1.0900       1.1180       1.1
2502   5   8.0000       870.00       120    1400.0       1600.0
2507   5   1800.0       2000.0       220    2600.0       5.0000
2512   5   .0           .20000       .40    .60000       .80000
2518   5   .26000       .26500       .27    .28000       .29000
2524   5   .52000       .52700       .54    .56000       .59000
2530   5   .68000       .69000       .70    .73000       .76000
2536   5   .82000       .82400       .84    .86800       .90000
2542   5   .92000       .93000       .95    .98000       1.0200
2548   5   1.0000       1.0020       1.0    1.0500       1.0900
2554   5   1.0520       1.0550       1.0    1.1000       1.1310
2560   5   1.0900       1.1000       1.1    1.1350       1.1650
1601   2   3.0000       -9.0000
1603   5   .74918E-02   -.28000E-01  .26    .27600       2.4500
1608   1   .86500
1609   5   .79059E-02   2.8200       .90    1.1700       .12400E-02
1614   2   .75600       .74300
1616   5   10.000       .0           .40    .70000E-02   .90000E-02
1621   5   .10000E-01   .11000E-01   .11    .12000E-01   .15500E-01
1626   5   .22000E-01   1.0180       1.0    1.1540       1.2330
1631   5   1.2790       1.3140       1.3    1.3370       1.3640
1636   1   1.3970
   1   5   1.0000       1.0000       2.0    .C           1.0000
   6   5   4.0000       4.0000       1.0    1.0000       3.0000
  11   5   1.0000       2.0000       .C     1.0000       1.0000
  16   4   2.0000       2.0000       2.0    .0
  22   5   2.0000       25000.       .C     .0           .0
  27   5   .0           .33000       220    220.00       3.5000
  32   5   1.0000       .0           1.0    1.0000       2.0000
  37   5   4.0000       3.0000       4.0    9.0000       2.0000
  42   5   8.0000       6.0000       3.0    4.0000       60.000
  47   1   100.00
 103   1   .50000
 105   5   .20000       .12000       .0     .50000       1.0000
 110   5   .20000       .80000       4.0    1.1500       .12000
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 115     2     .16200E-01    .50000
 120     5     .0            .0             7.0      6.5000        1.3000
 125     5     1.0000        12.000         .0       .55000        5.0000
 130     2     .30000        1.1000
 136     5     .45000        .15000         .80      .85000        .50000
 141     5     180.00        .35000E-01     2.0      .73000E-01    .10000
 146     5     .35000E-01    2.0000         .78      .0            .0
 151     1     .10000
 152     5     .40000        .20000         .50      .40000        3.0000
 171     3     3.0000        1.0000         11.
 176     5     4.0000        -9.0000        .25      .75000E-01    .10000
 181     5     725.00        .12000         1.0      165.00        3000.0
 186     5     43.200        .11000         1.7      1.3500        1.0000
 191     3     1.5300        .0             .65
 203     5     5.0000        -4.0000        .30      .75000E-01    690.00
 208     5     .17000        .33000         .75      1.0000        .72000
 213     3     1.0000        1.0000         1.0
 216     1     .0
 217     1     1.7610
 219     3     2.0000        2.0000         1.0
 223     5     .97000        100.00         1.0      1.0000        4000.0
 228     5     1.0000        50.300         1.1      .0            .95000
 233     5     .0            2.0000         300      170.00        43.200
 238     4     1.1050        .75000         .30      .0
 242     1     1.7610
 245     1     1.0000
 246     2     2.0000        1.1050
 248     5     1.0000        900.00         10.      .75000E-01    .97000
 253     1     .0
 254     2     .82000        .33000
 257     2     140.00        3.0000
 261     1     4.0000
 262     4     .0            .20000         .40      .80000
 272     4     .85000        .83000         .80      .78000
 312     4     1130.0        .55500         .75      1.0000
 323     1     .0
 327     1     1.0200
 328     2     .14640E+07    6.2800
 330     1     7.0000
 331     5     .0            .20000         .40      .60000        .80000
 336     2     1.0000        1.4000
 339     5     .60000E-02    .62000E-02     .70      .80000E-02    .95000E-02
 344     2     .12000E-01    .20000E-01
2602     3     2200.0        450.00         200
2605     3     100.00        .0             .0
2608     5     .0            .0             .0       .0            .0
2613     5     25.000        25.000         25.      .0            .0
2618     4     30.000        .18000         25.      .0
2622     5     125.00        2.0800         .40      .80000        .0
2627     5     1.0000        .0             2.0      2.0000        24.100
2632     5     1.0000        .75000         1.0      .75000        .0
2637     5     44.000        2.2000         61.      .28600        1.1500
2642     5     14.200        14.200         1.0      1.0000        250.00
2647     5     3.0000        250.00         250      1.0000        .11000
2652     2     .17000        .17000
2654     5     1.0000        1.0000         1.0      1.0000        1.0000
2659     5     1.0000        1.0000         1.0      1.0000        1.0000
2664     5     1.0000        1.0000         1.0      1.0000        1.0000
2669     5     1.0000        1.0000         1.0      1.0000        1.0000
 347     5     3.0000        3.0000         .0       .50000        1.0000
 354     3     .0            .50000         1.0
 361     3     1.0000        1.0000         1.0
 368     3     1.0000        1.0000         1.0
```

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 375        3      1.0000       1.0000       1.0
 401        1      .0
 411        1      .33300E-01
 421        1      .0
 431        1      1.0000
 441        1      1.1050
 461        2      1.0000       1.0000
 481        2      .0           .0
 501        2      .0           .0
 511        2      .0           .0
 521        2      1.0600       1.0600
 531        2      .20000E-01   .20000E-01
 541        2      1.1050       1.1050
 551        2      .10000       .20000
 571        2      1.0000       1.0000
 591        2      .0           .0
 601        2      .30000       .40000
 611        2      .0           .0
 621        2      500.00       500.00
 631        2      2.0000       2.0000
 641        2      5000.0       3000.0
 651        2      1.1050       1.1050
 661        2      6.0000       6.0000
 671        2      1.1050       1.1050
 681        2      1.0000       1.0000
 691        2      .0           .0
 701        2      1.0000       1.0000
 721        3      2.0000       4.0000       4.0
 731        1      170.00
 741        3      .0           .0           .0
 751        3      .50000       .50000       .50
 761        3      .0           .0           .0
 771        3      15.000       15.000       15.
 781        3      2.0000       2.0000       2.0
 791        3      60.000       150.00       300
 801        3      1.1050       1.1050       1.1
 811        3      .0           .0           .0
 821        3      1.1050       1.1050       1.1
 831        3      .0           .0           .0
 841        3      .55000       .60000       .70
 851        3      .0           .0           .0
1031        2      .0           .0
1041        2      .40000       .40000
1051        2      .0           .0
1061        2      .50000E-01   .50000E-01
1071        2      1.1050       1.1050
1081        2      .50000       .25000
1091        2      1.1050       1.1050
1101        2      .0           .0
1111        1      .35000
1121        2      .0           .0
1131        2      .0           .0
1161        1     -1000.0
1171        1      .10000E-01
1181        1      1000.0
1191        1      1.0000
WG = 0.250000E+05  WPA = 0.0           WFR = 0.0
WG = 0.250000E+05  WFA = 0.738579E+04  WFR = 0.512283E+04
WG = 0.217672E+05  WFA = 0.580161E+04  WFR = 0.453304E+04
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```
                                       H E S C O M P
           HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM     E-

    SINGLE ROTOR
              COMPOUND HELICOPTER
                                AUX. INDEPENDENT I/SHAFT CRUIISION


S I Z E   D A T A   THIS RUN CONVERGED IN   3 ITERATIONS

                              GROSS WEIGHT =   17643.   LB
         FUSELAGE

             LF          LENGTH(BODY+TAILBOOM)                 50.1 FT.
             LC          LENGTH(CABIN)                         12.0 FT.
             LB          LENGTH(BODY)                          27.5 FT.
             LTB         LENGTH(TAILBOOM)                      22.6 FT.
             XM          FWD. ROTOR LOCATION                   15.1 FT.
             WF          WIDTH                                  6.5 FT.
             SF          WETTED AREA                          737.5 SQ. FT.

         WING

             AR          ASPECT RATIO                          4.51
             SW          AREA                                 113.3 SQ. FT.
             BW          SPAN                                  22.6 FT.
             CEABW       MEAN CHORD                             5.0 FT.
             LAMBDA C/4  QUARTER CHORD SWEEP                    0.0 DEG.
             LAMBDA      TAPER RATIO                          0.500
             (T/C)R      ROOT THICKNESS/CHORD                 0.200
             (T/C)T      TIP THICKNESS/CHORD                  0.120
             WG/SW       WING LOADING                         155.7 LBS/SQ. FT.
             GRW         ROTOR/WING GAP                         8.6 FT.
             CF/C        FLAP CHORD/MEAN CHORD RATIO          1.000
         HOR. TAIL

             ARHT        ASPECT RATIO                         4.000
             SHT         AREA                                  35.5 SQ. FT.
             BHT         SPAN                                  11.9 FT.
             CEABHT      MEAN CHORD                             3.0 FT.
             LAMBDA H    TAPER RATIO                          0.500
             (T/C)HT     THICKNESS/CHORD                      0.120
             LTH         HOR. TAIL ARM                         26.0 FT.
         VERT. TAIL

             ARVT        ASPECT RATIO                         1.523
             SVT         AREA                                  21.2 SQ. FT.
             BVT         SPAN                                   5.7 FT.
             CEARVT      MEAN CHORD                             3.7 FT.
             LAMBDA VT   TAPER RATIO                          0.450
             ZTR         TAIL ROTOR(VERT.) LOCATION             4.6 FT.
             ZETAVT      TAIL ROTOR/VERT. TAIL OVERLAP RATIO  0.800
             (T/C)VT     THICKNESS/CHORD                      0.150
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                                       H E S C O M P
                 HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM     E-

      SINGLE ROTOR
                 COMPOUND HELICOPTER
                                  AUX. INDEPENDENT T/SHAFT CRUISION


   S I Z E   D A T A   THIS RUN CONVERGED IN  3 ITERATIONS

                               GROSS WEIGHT =   17643.   LB

        FUSELAGE

          LF            LENGTH(BODY+TAILBOOM)                  50.1 FT.
          LC            LENGTH(CABIN)                          12.0 FT.
          LB            LENGTH(BODY)                           27.5 FT.
          LTB           LENGTH(TAILBOOM)                       22.6 FT.
          XM            FWD. ROTOR LOCATION                    15.1 FT.
          WF            WIDTH                                   6.5 FT.
          SF            WETTED AREA                           737.5 SQ.  FT.

        WING

          AR            ASPECT RATIO                           4.51
          SW            AREA                                  113.3 SQ.  FT.
          BW            SPAN                                   22.6 FT.
          CBARW         MEAN CHORD                              5.0 FT.
          LAMBDA C/4    QUARTER CHORD SWEEP                     0.0 DEG.
          LAMBDA        TAPER RATIO                           0.500
          (T/C)R        ROOT THICKNESS/CHORD                  0.200
          (T/C)T        TIP THICKNESS/CHORD                   0.120
          WG/SW         WING LOADING                          155.7 LBS/SQ. FT.
          GRW           ROTOR/WING GAP                          8.6 FT.
          CF/C          FLAP CHORD/MEAN CHORD RATIO           1.000
        HOR. TAIL

          ARHT          ASPECT RATIO                          4.000
          SHT           AREA                                   35.5 SQ.  FT.
          BHT           SPAN                                   11.9 FT.
          CBARHT        MEAN CHORD                              3.0 FT.
          LAMBDA H      TAPER RATIO                           0.500
          (T/C)HT       THICKNESS/CHORD                       0.120
          LTH           HOR. TAIL ARM                          26.0 FT.
        VERT. TAIL

          ARVT          ASPECT RATIO                          1.523
          SVT           AREA                                   21.2 SQ.  FT.
          BVT           SPAN                                    5.7 FT.
          CBARVT        MEAN CHORD                              3.7 FT.
          LAMBDA VT     TAPER RATIO                           0.450
          ZTR           TAIL ROTOR(VERT.) LOCATION              4.6 FT.
          ZETAVT        TAIL ROTOR/VERT. TAIL OVERLAP RATIO   0.800
          (T/C)VT       THICKNESS/CHORD                       0.150
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MAIN ROTOR PYLON

     AR              ASPECT RATIO                                 0.500
     SPP             WETTED AREA                                 39.1 SQ. FT.
     FAPP            FRONTAL AREA                                 6.2 SQ. FT.
     HP1             HEIGHT                                       3.0 FT.
     CBARPP          MEAN CHORD                                   6.0 FT.
     LAMBDA PP       TAPER RATIO                                  0.400
     (T/C)R          ROOT THICKNESS/CHORD                         0.400
     (T/C)T          TIP THICKNESS/CHORD                          0.200

PRIMARY ENGINE NACELLE

     LN              LENGTH                                       5.8 FT.
     DN              MEAN DIAMETER                                2. FT.
     SN              WETTED AREA(TOTAL FOR ALL ENGINES)          60.8 SQ. FT.

AUXILIARY INDEPENDENT ENGINE NACELLE

     LNI             LENGTH                                       4.8 FT.
     DNI             MEAN DIAMETER                                1. FT.
     SNI             WETTED AREA(TOTAL FOR ALL ENGINES)          19. SQ. FT.

AUXILIARY INDEPENDENT ENGINE NACELLE STRUT

     SSTR            WETTED AREA(TOTAL)                        .  0. SQ. FT.
     BNS             SPAN                                         0.1 FT.
     CNS             MEAN CHORD                                   2.8 FT.

PROPELLER(AUXILIARY PROPULSION)

     DAB             DIAMETER                                    10.0 FT.
     AF              ACTIVITY FACTOR PER BLADE                  140.0
     SIGAR           SOLIDITY                                     0.171
     NRA             NO. OF PROPELLERS                            1.
     NO. BLADES      NO. OF BLADES/PROP                           3.
     VTIP            TIP SPEED                                  900. FT./SEC

MAIN ROTOR

     DMR             DIAMETER                                    45.2 FT.
     SIGMR           SOLIDITY                                     0.128
     WG/A            DISC LOADING                                11.0 LB/SQ. FT.
     CT/SIGMA        THRUST COEFF./SOLIDITY                       0.110
     NR              NO. OF ROTORS                                1.
     NO. BLADES      NO. OF BLADES/ROTOR                          4.
     THETA           BLADE TWIST                                 -9.000 DEG.
     XC              BLADE CUTOUT/RADIUS RATIO                    0.250
     VTIP            TIP SPEED                                  725. FT./SEC.

TAIL ROTOR

     DTR             DIAMETER                                    10.8 FT.
     SIGTR           SOLIDITY                                     0.237
     (T/A)NET        NET DISC LOADING                            17.6 LB./SQ. FT.
     CT/SIGMA        THRUST COEFF./SOLIDITY                       0.170
     NO. BLADES      NO. OF BLADES/ROTOR                          5.
     THETA           BLADE TWIST                                 -4.000 DEG.
     XCTR            BLADE CUTOUT/RADIUS RATIO                    0.300
     G               MAIN/TAIL ROTOR GAP                          1.0 FT.
     VTIP            TIP SPEED                                  690. FT./SEC.
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                                          H E S C O M P
                  HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM     E-


W E I G H T S   D A T A     IN LBS

          MLF           MANEUVER LOAD FACTOR
          GLF           GUST LOAD FACTOR
          ULF           ULTIMATE LOAD FACTOR

      PROPULSION GROUP
             WMRG       TOTAL MAIN ROTOR GROUP                         .
          K12 WMRB          MAIN ROTOR BLADE (PER ROTOR)            1023.
          K13 WMRH          MAIN ROTOR HUB (PER ROTOR)               511.
              WBF           BLADE FOLDING(PER ROTOR)                 230.
          K15 WAR       AUXILIARY PROPULSION ROTOR GROUP               .
              WDS       DRIVE SYSTEM                                   .
          K16 WMRDS         MAIN ROTOR DRIVE SYSTEM                 1359.
          K20 WTRDS         TAIL ROTOR DRIVE SYSTEM                  118.
          K17 WADS          AUXILIARY PROPULSION DRIVE SYSTEM        205.
          K18 WEP       PRIMARY ENGINES                                .
          K19 WEA       AUXILARY ENGINES                               .
              WPEI      PRIMARY ENGINE INSTALLATION                    .
              WAEI      AUXILIARY ENGINE INSTALLATION                  .
              WFS       FUEL SYSTEM                                    .
          DELTA WP      PROPULSION GROUP WEIGHT INCREMENT              .
                WP   TOTAL PROPULSION GROUP WEIGHT                              5091.

      STRUCTURES GROUP
          K8  WW        WING                                           .
              WTG       TAIL GROUP                                     .
          K9  WHT           HOR. TAIL                                 71.
          K14 WTR           TAIL ROTOR                               123.
          K6  WB        FUSELAGE                                       .
          K7  WLG       LANDING GEAR                                   .
              WNG           NOSE GEAR                                141.
              WMG           MAIN GEAR                                565.
              WTES      TOTAL ENGINE SECTION                           .
              WPES          PRIMARY ENGINE SECTION                   145.
              WAES          AUXILIARY ENGINE SECTION                  51.
          DELTA WST     STRUCTURE WEIGHT INCREMENT                     .
                WST  TOTAL STRUCTURE WEIGHT                                     3272.

      FLIGHT CONTROLS GROUP
              WPFC      PRIMARY FLIGHT CONTROLS                        .
              WCC           COCKPIT CONTROLS                          81.
          K1  WRC           MAIN ROTOR CONTROLS                      356.
          K2  WSC           MAIN ROTOR SYSTEMS CONTROLS              248.
          K3  WFW           FIXED WING CONTROLS                        0.
              WTM           TILT MECHANISM                             0.
              WSAS          SAS                                       30.
              WAFC      AUXILIARY FLIGHT CONTROLS                      .
          K4  WRCA          AUX. PROPULSION ROTOR CONTROLS            24.
          K5  WSCA          AUX. PROPULSION ROTOR SYS. CONTRO         32.
              WMC           MISCELLANEOUS CONTROLS                     0.
          DELTA WFC     CONTROL WEIGHT INCREMENT                       .
                WFC  TOTAL CONTROL WEIGHT                                        870.
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WFE       WEIGHT OF FIXED EQUIPMENT          2200.
WE        WEIGHT EMPTY                      11433.
WFUL      FIXED USEFUL LOAD                   450.
OWE       OPERATING WEIGHT EMPTY            11883.
WPL       PAYLOAD                            2000.
(WF)A     FUEL                               3760.
WG        GROSS WEIGHT                      17643.
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A E R O D Y N A M I C S   D A T A
                FE              TOTAL EFFECTIVE FLATPLATE AREA                   SQFT
                SWET            TOTAL WETTED AREA                                SQFT
                CFAVF           MEAN SKIN FRICTION COEFF.
            D R A G   B R E A K D O W N           IN  SQFT
                FEW             WING FE                                     .729
                FEF             FUSELAGE FE                                 .233
                FEFP            FORWARD(MAIN) ROTOR PYLON FE                .0
                FEAP            AFT ROTOR PYLON FE                          .0
                FEMRH           MAIN ROTOR HUB(S) FE                        .0
                FETRH           TAIL ROTOR HUB FE                           .0
                FEVT            VERTICAL TAIL FE                            .0
                FEHT            HORIZONTAL TAIL FE                          .0
                FEN             PRIMARY ENGINE NACELLE FE                   .0
                FENI            AUX. INDEPENDENT CRUISE ENG. NAC. FE        .0
                FENS            AUX. INDEPENDENT CRUISE ENG. STRUT FE       .0
                DELTA FE        INCREMENTAL FE                              .0
A E R O D Y N A M I C   C O E F F .
                A5                                                          79
                A6                                                          64
                A7                                                          20
                A8                                                          13
                A9                                                          48
                E          WING LIFT EFFICIENCY FACTOR                     0.
                EVT        VERTICAL TAIL LIFT EFFICIENCY FACTOR            0.
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R O T O R   D A T A

          ROTOR CYCLE NO.     3.0000

          MAIN ROTOR SOLIDITY SIZED BY MANUEVER CONDITIONS
          H =      3000.0 FT. , TEMP =       91.5 DEG. , V =     KT.
          100.0 PERCENT HOVER RPM
          ROTOR MANUEVER G'S =  1.350 , CT/SIGMA = 0.110

          TAIL ROTOR SIZED AT       1.050 TIMES THE SOLIDITY
          REQUIRED TO SATISFY HOVERING TURN REQUIREMENTS AT :
                        H                                =     4000
                        TEMP                             =     95.0F.
                        CTG/CTNET                        =      1.2
                        YAW RATE                         =      0.7EC.
                        YAW ACCELERATION                 =      0.3EC2
                        TAIL ROTOR POLAR
                        MOM. OF INERTIA(PER BLADE)       =      4.1FT2
                        HELICOPTER YAW
                        MOM. OF INERTIA                  =    36385FT2
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P R O P U L S I O N   D A T A
         PRIMARY PROPULSION CYCLE NO.     1.761
                 TURBOSHAFT ENGINE

                  2.  ENGINES

            BHP*E            MAX. STANDARD S.L. STATIC H.P.             H.P.

            ENGINE SIZED FOR TAKEOFF AT T/W =1.06
             95.0 PERCENT MILITARY POWER SETTING,
            H = 4000.  FT, TEMPERATURE = 95.04 DEG.F.,
             0.0   ENGINES INOPERATIVE, AND    0.0  FT/MIN VERTI OF CLIMB.

         AUX. INDEPENDENT PROPULSION CYCLE NO.     1.761
                 TURBOSHAFT ENGINE

                  1.  ENGINES

            BHP*PI            MAX. STANDARD S.L. STATIC H.P.        .     H.P.

            ENGINE SIZED FOR CRUISE AT VC = 170. KNOTS,
             NORMAL  POWER SETTING,
            HC =  3000. FT, TEMPERATURE =  91.50 DEG.F.,
            AND  0.0   ENGINES INOPERATIVE.


                MAIN AND TAIL ROTOR DRIVE SYSTEM RATING            H.P.

                MAIN ROTOR DRIVE SYSTEM RATING          2914.

         XMSN SIZED AT 100. PERCENT OF MAIN ROTOR HOVER POWER REQ
       . AT H = 4000. FT, TEMP = 95.04 DEG.F., 100.0 PERCENT HOVE
                TAIL ROTOR DRIVE SYSTEM RATING           436.

         XMSN SIZED AT 100. PERCENT OF TAIL ROTOR HOVER POWER REQ
         AT H = 4000. FT, TEMP = 95.04 DEG.F., 100.0 PERCENT HOVE

                AUXILIARY INDEPENDENT PROPULSION DRIVE SYSTEM RA         871.     H.P.

         XMSN SIZED AT 100. PERCENT OF AUX. PROPULSION CRUISE POWRE  AT VC =170. KT,
         HC =  3000. FT, TEMP= 91.50 DEG.F.
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                               H E S C O M P
              HELICOPTER SIZING & PERFORMANCE COMPUTER PROGRAM     E-

            MISSION PERFORMANCE DATA

     TAXI   FOR   0.033   HRS.  AT GROUND IDLE ENGINE RATING
                                                              PRIM.      PRIM.    TOTAL       AUX.       AUX.      AUX.     AUX. ENG.   TEMP.
                     FUEL                  PRESS.             TURB.      ENG.     FUEL        TURB.      ENG.      ENG.     FUEL FLOW    DEG.
  TIME      RANGE    USED      WEIGHT      ALT.       TAS     TEMP.      CODE     FLOW        TEMP.      CODE      PERF     (LBS/HR)    (F)
  (HRS)     (N.M.)   (LBS)     (LBS.)      (FT)       (KTS)   (R)                 (LBS/HR)    (R)

  0.0         0.0      0.0     17643.        0.        0.0     950.0      T         438.      550.0       T        0.0         95.       59.0
  0.033       0.0     14.6     17628.        0.        0.0     950.0      T         438.      550.0       T        0.0         95.       59.0

     TAKEOFF, HOVER, OR LAND AT   T/W = 1.060 FOR   0.100 HRS.

                                                              PRIM.      PRIM.    TOTAL       THRUST
                     FUEL                  PRES.              TURB.      ENG.     FUEL          TO
  TIME      RANGE    USED      WEIGHT      ALT.       TAS     TEMP.      CODE     FLOW        WEIGHT      FM        BHP        CT      CT/SIGMA
  (HRS)     (N.M.)   (LBS)     (LBS.)      (FT)       (KTS)   (R)                 (LBS/HR)

  M.ROTOR   M.ROTOR  T.ROTOR   T.ROTOR     VRC     PRIM.ENG    AUX.ENG    ROTLI    TEMP
   VTIP      RHP      VTIP      RHP        RHP     FUEL FLOW  FUEL FLOW   CODE     DEG.      DELDCM      FMI      CPPRO      CPIND       COC
                     (FPS)                         (LBS/HR)   (LBS/HR)             (F)

  0.033       0.0     14.6     17628.        0.        0.0    1685.7      P        1527.      1.060     0.705      2889.    0.0093      0.073
  725.0     2387.    690.0       318.        0.     1432.        95.      A        59.0      0.0       0.705    0.00011    0.00079     0.0068

  0.053       0.0     45.1     17598.        0.        0.0    1684.2      P        1524.      1.060     0.705      2881.    0.0093      0.073
  725.0     2380.    690.0       317.        0.     1429.        95.      A        59.0      0.0       0.705    0.00011    0.00079     0.0068

  0.073       0.0     75.6     17567.        0.        0.0    1682.8      P        1521.      1.060     0.705      2872.    0.0093      0.073
  725.0     2373.    690.0       316.        0.     1427.        95.      A        59.0      0.0       0.705    0.00011    0.00079     0.0068

  0.093       0.0    106.0     17537.        0.        0.0    1681.3      P        1519.      1.060     0.705      2864.    0.0093      0.072
  725.0     2367.    690.0       314.        0.     1424.        95.      A        59.0      0.0       0.705    0.00011    0.00079     0.0068

  0.113       0.0    136.4     17507.        0.        0.0    1679.9      P        1516.      1.060     0.705      2856.    0.0093      0.072
  725.0     2360.    690.0       313.        0.     1421.        95.      A        59.0      0.0       0.705    0.00011    0.00078     0.0068

  0.133       0.0    166.7     17476.        0.        0.0    1678.5      P        1513.      1.060     0.705      2848.    0.0092      0.072
  725.0     2353.    690.0       312.        0.     1418.        95.      A        59.0      0.0       0.705    0.00011    0.00078     0.0068

  0.133       0.0    166.7     17476.        0.        0.0    1678.5      P        1513.      1.060     0.705      2848.    0.0092      0.072
  725.0     2353.    690.0       312.        0.     1418.        95.      A        59.0      0.0       0.705    0.00011    0.00078     0.0068
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      CRUISE AT   170.0  KNOTS TAS, LIMITED BY  NORMAL   ENGINE RATING

                                                           PRIM.    PRIM.                      CT PRIME
                             FULL                 PRES.             TURB.   . ENG.                        OVER     ALPHA      SPEC.
   TIME       RANGE          USED      WEIGHT     ALT.       TAS    TEMP.     CODE     EAS      MU        SIGMA    D/L        RANGE        BHP
   (HRS)      (N.M.)         (LBS)     (LBS.)     (FT)      (KTS)   (R)                (KTS)                       (DEG)      (NM/P)

                                                                                                 AUX.     AUX.     AUX.                     AUX.
   M.ROTOR    M.ROTOR        T.ROTOR   T.ROTOR    PROP     PRIM.ENG   BHP      ETAP   AUX. ENG.  TURB.    ENG.     ENG.                ENG. BHP
    VTIP       RHP            VTIP      RHP       VTIP     FUEL FLOW  AUX      PROP   FUEL FLOW  TEMP.    CODE     PERF                OR THRUST
   (FPS)                     (FPS)                (FPS)    (LBS/HR)                   (LBS/HR)

   CPPRO      CPIND          CPPAR     CPNUD      CDO      DELCDS    DELCDM    CXR       J       CP        CT       CLW        CDW          KN


   0.133         0.0         166.7      17476.        0.       170.0    1604.6      P     170.0    0.396    0.046     -5.0      .10066       2545.
   725.0       2216.         650.0        156.    ----        1239.     ----    0.821    400.    1679.4      P       0.620                  1119.
   0.000478 0.000049      0.000265   0.000042  0.01735     0.00012   0.00933 0.000517   ----     ----     ----      0.500      0.007        0.682

   0.222       15.00         315.7      17327.        0.       170.0    1602.8      P     170.0    0.396    0.046     -5.0      .10051       2534.
   725.0       2206.         650.0        155.    ----        1235.     ----    0.821    400.    1679.0      P       0.619                  1119.
   0.000476 0.000048      0.000265   0.000042  0.01727     0.00010   0.00927 0.000517   ----     ----     ----      0.500      0.007        0.680

   0.310       30.00         464.4      17179.        0.       170.0    1600.9      P     170.0    0.396    0.045     -5.1      .10116       2523.
   725.0       2195.         650.0        155.    ----        1281.     ----    0.821    400.    1678.5      P       0.618                  1119.
   0.000474 0.000047      0.000269   0.000041  0.01720     0.00009   0.00921 0.000516   ----     ----     ----      0.500      0.007        0.677

   0.398       45.00         612.7      17030.        0.       170.0    1599.1      P     170.0    0.396    0.045     -5.1      .10140       2512.
   725.0       2185.         650.0        154.    ----        1277.     ----    0.821    399.    1678.0      P       0.618                  1119.
   0.000472 0.000046      0.000268   0.000041  0.01713     0.00008   0.00915 0.000516   ----     ----     ----      0.500      0.007        0.674

   0.486       60.00         760.6      16882.        0.       170.0    1597.3      P     170.0    0.396    0.044     -5.2      .10134       2501.
   725.0       2175.         650.0        154.    ----        1273.     ----    0.821    399.    1677.6      P       0.617                  1119.
   0.000471 0.000044      0.000268   0.000040  0.01707     0.00008   0.00909 0.000515   ----     ----     ----      0.500      0.007        0.671
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      CRUISE AT SPEED FOR 99 PER CENT BEST RANGE WITH HEADWIND OF    0.0

                                                            PRIM.     PRIM.                          CT PRIME
TIME      RANGE      FUEL                   PRES.           TURB.     ENG.                           OVER      ALPHA      SPEC.
(HRS)     (N.M.)     USED       WEIGHT      ALT.    TAS     TEMP.     CODE      EAS       MU         SIGMA     C/L        RANGE         BHP
                     (LBS)      (LBS.)      (FT)    (KTS)   (R)                 (KTS)                          (DEG)      (NMPP)

                                                                                          AUX.       AUX.      AUX.                   AUX.
M.ROTOR   M.ROTOR    T.ROTOR    T.ROTOR     PROP    PRIM.ENG   BHP      ETAP    UX. ENG.  TURB.      ENG.      ENG.               ENG. BHP
 VTIP      RHP        VTIP       RHP        VTIP    FUEL FLOW  AUX      PROP    UEL FLOW  TEMP.      CODE      PEHF               OR THRUST
(FPS)                (FPS)                  (FPS)   (LBS/HR)                    (LBS/HR)

CPPRO     CPINC      CPPAR      CPHUD       CDO     DELCDS    DELCDM    CXR       J       CP         CT        CLW        CDV           RN


0.587       67.95      845.5     16797.     5000.     149.1    1517.6      P      138.4    0.347     0.059      -2.8      .11667        1877.
725.0       1616.      690.0       108.     ----       994.    ----      0.826     285.   1538.1       P        0.471                   549.
0.000412 0.000092  0.000153   0.000054  0.01654   0.00021   0.00843  0.000371   ----     ----      ----       0.500      0.007        0.781

0.688       82.95      974.1     16669.     5000.     149.1    1515.6      P      138.4    0.347     0.059      -2.8      .11700        1867.
725.0       1606.      690.0       107.     ----       991.    ----      0.826     285.   1537.7       P        0.471                   548.
0.000410 0.000090  0.000152   0.000054  0.01647   0.00019   0.00837  0.000370   ----     ----      ----       0.500      0.007        0.779

0.788       97.95     1102.3     16541.     5000.     149.1    1513.6      P      138.4    0.347     0.058      -2.9      .11734        1856.
725.0       1597.      690.0       107.     ----       987.    ----      0.826     284.   1537.3       P        0.470                   547.
0.000408 0.000088  0.000152   0.000053  0.01640   0.00018   0.00832  0.000370   ----     ----      ----       0.500      0.007        0.778

0.889      112.95     1230.2     16413.     5000.     149.1    1511.6      P      138.4    0.347     0.058      -2.9      .11766        1846.
725.0       1587.      690.0       107.     ----       984.    ----      0.826     284.   1536.8       P        0.470                   547.
0.000406 0.000086  0.000152   0.000053  0.01633   0.00017   0.00826  0.000370   ----     ----      ----       0.500      0.007        0.776

0.989      127.95     1357.6     16285.     5000.     149.1    1509.7      P      138.4    0.347     0.057      -2.9      .11799        1836.
725.0       1578.      690.0       106.     ----       981.    ----      0.826     284.   1536.4       P        0.469                   546.
0.000405 0.000084  0.000152   0.000052  0.01626   0.00015   0.00821  0.000369   ----     ----      ----       0.500      0.007        0.774

1.090      142.95     1484.8     16158.     5000.     149.1    1507.7      P      138.4    0.347     0.056      -2.9      .11832        1826.
725.0       1569.      690.0       106.     ----       977.    ----      0.826     284.   1536.0       P        0.469                   546.
0.000403 0.000083  0.000152   0.000052  0.01620   0.00014   0.00815  0.000369   ----     ----      ----       0.500      0.007        0.772

1.137      150.00     1544.4     16099.     5000.     149.1    1506.8      P      138.4    0.347     0.056      -2.9      .11847        1822.
725.0       1565.      690.0       106.     ----       976.    ----      0.826     284.   1535.7       P        0.468                   545.
0.000402 0.000082  0.000152   0.000051  0.01616   0.00014   0.00813  0.000368   ----     ----      ----       0.500      0.007        0.772
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      CLIMB  TO  5000.  FT. WITH   MAXIMUM R/C  AT  NORMAL   ENGINE RAT
        ** TAS(AND EAS) IS THE HORIZONTAL COMPONENT OF THE FLIGHT PATH

                                                          PRIM.     PRIM.                    CT PRIME
                        FUEL                PRES.         TURB.     ENG.                       OVER     ALPHA
TIME       RANGE        USED      WEIGHT    ALT.    TAS   TEMP.     CODE     EAS      MU       SIGMA     D/L     GAMMA    BHP      R/C
(HRS)      (N.M.)       (LBS)     (LBS.)    (FT)   (KTS)  (R)                (KTS)                      (DEG)   (DEG)            (FPM)

                                                                                      AUX.     AUX.     ALX.
M.ROTOR   M.ROTOR     T.ROTOR    T.ROTOR    PROF  PRIM.ENG   BHP      ETAP   UX. ENG.  TURB.   ENG.     ENG.               AUX.
 VTIP      RHP         VTIP       RHP       VTIP  FUEL FLOW  AUX      PRCP   UEL FLOW  TEMP.   CODE     PERF            ENG. BHP
(FPS)                  (FPS)                (FPS) (LBS/HR)                   (LBS/HR)                                   OR THRUST

CPPRO     CPINC       CPPAR      CPNUD      CDO     DELCDS   DELCDM    CXR     J       CP       CT       CLW      CDW      KN


0.486        60.00     760.6     16882.        0.     76.4   1856.0      T     76.4   0.180    0.063    -2.4     7.3     1949. 1012.
725.0        1121.     650.0        64.     ----      896.     ----   0.820      0.  1856.0      T     0.835                0.
0.000152  0.000200  0.000061  0.000011   0.00830  0.00000  0.00047 0.000332  ----    ----     ----    0.300   0.007     0.959

0.494        60.64     768.0     16875.      500.     76.4   1856.0      T     75.9   0.180    0.064    -2.3     7.1     1928.  976.
725.0        1123.     650.0        64.     ----      885.     ----   0.820      0.  1856.0      T     0.837                0.
0.000153  0.000206  0.000061  0.000011   0.00834  0.00000  0.00051 0.000333  ----    ----     ----    0.300   0.007     0.960

0.503        61.30     775.5     16868.     1000.     76.4   1856.0      T     75.3   0.180    0.065    -2.3     6.8     1907.  939.
725.0        1125.     650.0        63.     ----      874.     ----   0.820      0.  1856.0      T     0.838                0.
0.000154  0.000213  0.000061  0.000011   0.00838  0.00000  0.00055 0.000334  ----    ----     ----    0.300   0.007     0.960

0.512        61.99     783.3     16860.     1500.     77.4   1856.0      T     75.7   0.183    0.066    -2.3     6.5     1887.  902.
725.0        1129.     650.0        63.     ----      864.     ----   0.820      0.  1856.0      T     0.840                0.
0.000156  0.000216  0.000063  0.000012   0.00845  0.00000  0.00062 0.000342  ----    ----     ----    0.300   0.007     0.960

0.521        62.71     791.3     16852.     2000.     77.4   1856.0      T     75.2   0.183    0.067    -2.3     6.2     1866.  864.
725.0        1132.     650.0        63.     ----      853.     ----   0.820      0.  1856.0      T     0.841                0.
0.000157  0.000223  0.000064  0.000012   0.00850  0.00001  0.00067 0.000343  ----    ----     ----    0.300   0.007     0.960

0.531        63.47     799.5     16844.     2500.     77.4   1856.0      T     74.6   0.183    0.068    -2.3     5.9     1846.  825.
725.0        1135.     650.0        63.     ----      842.     ----   0.820      0.  1856.0      T     0.843                0.
0.000157  0.000230  0.000064  0.000012   0.00855  0.00001  0.00071 0.000344  ----    ----     ----    0.300   0.007     0.961

0.541        64.26     808.0     16835.     3000.     78.4   1856.0      T     75.0   0.185    0.069    -2.3     5.6     1825.  786.
725.0        1140.     650.0        62.     ----      832.     ----   0.820      0.  1856.0      T     0.844                0.
0.000160  0.000233  0.000066  0.000013   0.00864  0.00001  0.00080 0.000352  ----    ----     ----    0.300   0.007     0.960

0.551        65.11     816.8     16826.     3500.     78.4   1856.0      T     74.5   0.185    0.070    -2.3     5.3     1804.  747.
725.0        1144.     650.0        62.     ----      821.     ----   0.820      0.  1856.0      T     0.846                0.
0.000161  0.000240  0.000066  0.000013   0.00870  0.00001  0.00086 0.000353  ----    ----     ----    0.300   0.007     0.961

0.563        65.99     826.0     16817.     4000.     79.4   1856.0      T     74.8   0.187    0.071    -2.3     5.0     1784.  707.
725.0        1149.     650.0        62.     ----      811.     ----   0.820      0.  1856.0      T     0.847                0.
0.000163  0.000244  0.000069  0.000013   0.00881  0.00002  0.00096 0.000361  ----    ----     ----    0.300   0.007     0.961

0.574        66.94     835.5     16807.     4500.     79.4   1856.0      T     74.3   0.187    0.072    -2.3     4.7     1763.  666.
725.0        1153.     650.0        62.     ----      801.     ----   0.820      0.  1856.0      T     0.849                0.
0.000165  0.000252  0.000069  0.000013   0.00887  0.00002  0.00102 0.000362  ----    ----     ----    0.300   0.007     0.961

0.587        67.95     845.5     16797.     5000.     79.4   1856.0      T     73.7   0.187    0.073    -2.2     4.4     1743.  626.
725.0        1158.     650.0        61.     ----      790.     ----   0.820      0.  1856.0      T     0.850                0.
0.000166  0.000260  0.000069  0.000014   0.00894  0.00003  0.00109 0.000364  ----    ----     ----    0.300   0.007     0.962
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TRANSFER ALTITUDE TO     1000. FT.

                           FUEL                   PRES.
  TIME        RANGE        USED        WEIGHT     ALT.
  (HRS)       (N.M.)       (LBS)       (LBS.)     (FT)
  1.137        150.00      1544.4       16099.     5000.
  1.137        150.00      1544.4       16099.     1000.

TAKEOFF, HOVER, OR LAND AT   T/W = 1.060 FOR   0.200 HRS.

                                                           PRIM.      PRIM.   TOTAL      THRUST
                         FUEL                   PRES.              TURB.      ENG.    FUEL        TO
TIME        RANGE        USED        WEIGHT     ALT.        TAS    TEMP.      CODE    FLOW       WEIGHT     FM       BHP        CT       CT/SIGMA
(HRS)       (N.M.)       (LBS)       (LBS.)     (FT)       (KTS)   (R)                (LBS/HR)

M.ROTOR     M.ROTOR      T.ROTOR     T.ROTOR    VRC      PRIM.ENG  AUX.ENG    ROTLI   TEMP
 VTIP        RHP          VTIP        RHP       RHP      FUEL FLOW FUEL FLOW  CODE    DEG.       DELDCM     FM1      CPPRO      CPIND       CDO
                         (FPS)                           (LBS/HR)  (LBS/HR)           (F)

1.137        150.00      1544.4      16099.     1000.       0.0    1633.1      P      1390.      1.060     0.709      2544.    0.0088      0.068
725.0         2101.       690.0        270.        0.    1298.       92.       A        55.4    0.0       0.709    0.00011    0.00071     0.0068

1.157        150.00      1572.1      16071.     1000.       0.0    1631.9      P      1387.      1.060     0.709      2538.    0.0088      0.068
725.0         2095.       690.0        269.        0.    1295.       92.       A        55.4    0.0       0.709    0.00011    0.00071     0.0068

1.177        150.00      1599.9      16043.     1000.       0.0    1630.6      P      1385.      1.060     0.709      2531.    0.0087      0.068
725.0         2090.       690.0        268.        0.    1293.       92.       A        55.4    0.0       0.709    0.00011    0.00071     0.0068

1.197        150.00      1627.6      16015.     1000.       0.0    1629.4      P      1383.      1.060     0.709      2524.    0.0087      0.068
725.0         2084.       690.0        267.        0.    1291.       92.       A        55.4    0.0       0.709    0.00011    0.00070     0.0068

1.217        150.00      1655.3      15988.     1000.       0.0    1628.2      P      1380.      1.060     0.709      2517.    0.0087      0.068
725.0         2079.       690.0        266.        0.    1288.       92.       A        55.4    0.0       0.709    0.00011    0.00070     0.0068

1.237        150.00      1682.9      15960.     1000.       0.0    1627.0      P      1378.      1.060     0.709      2511.    0.0087      0.068
725.0         2073.       690.0        265.        0.    1286.       92.       A        55.4    0.0       0.709    0.00011    0.00070     0.0068

1.257        150.00      1710.4      15933.     1000.       0.0    1625.8      P      1376.      1.060     0.709      2504.    0.0087      0.068
725.0         2067.       690.0        264.        0.    1284.       92.       A        55.4    0.0       0.709    0.00011    0.00070     0.0068

1.277        150.00      1737.9      15905.     1000.       0.0    1624.6      P      1374.      1.060     0.709      2497.    0.0087      0.068
725.0         2062.       690.0        263.        0.    1282.       92.       A        55.4    0.0       0.709    0.00011    0.00070     0.0068

1.297        150.00      1765.4      15878.     1000.       0.0    1623.4      P      1371.      1.060     0.709      2490.    0.0086      0.068
725.0         2056.       690.0        262.        0.    1279.       92.       A        55.4    0.0       0.709    0.00011    0.00069     0.0068

1.317        150.00      1792.8      15850.     1000.       0.0    1622.2      P      1369.      1.060     0.709      2484.    0.0086      0.067
725.0         2051.       690.0        261.        0.    1277.       92.       A        55.4    0.0       0.709    0.00011    0.00069     0.0068

1.337        150.00      1820.2      15823.     1000.       0.0    1621.0      P      1367.      1.060     0.709      2477.    0.0086      0.067
725.0         2045.       690.0        260.        0.    1275.       92.       A        55.4    0.0       0.709    0.00011    0.00069     0.0068

1.337        150.00      1820.2      15823.     1000.       0.0    1621.0      P      1367.      1.060     0.709      2477.    0.0086      0.067
725.0         2045.       690.0        260.        0.    1275.       92.       A        55.4    0.0       0.709    0.00011    0.00069     0.0068
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CHANGE PAYLOAD,  REMOVE    1000.  LB.

                       FUEL                   PRES.
 TIME      RANGE       USED       WEIGHT      ALT.
 (HRS)     (N.M.)      (LBS)      (LBS.)      (FT)
 1.337      150.00     1820.2      15823.     1000.
 1.347      150.00     1820.2      14823.     1000.
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      LOITER  FOR  0.500 HRS.
                                                             PRIM.    . PRIM.                     CT PRIME
                      FUEL                PRES.              TURB.      ENG.                       OVER     ALPHA      TOTAL
 TIME      RANGE      USED      WEIGHT     ALT.      TAS     TEMP.      CODE      EAS       MU     SIGMA     D/L     FUEL FLOW      BHP
 (HRS)     (N.M.)     (LBS)     (LBS.)     (FT)     (KTS)     (R)                (KTS)                      (DEG)    (LBS/HR)

                                                                                           AUX.     AUX.     AUX.                    AUX.
M.ROTOR   M.ROTOR    T.ROTOR   T.ROTOR    PROP    PRIM.ENG    BHP       ETAP   AUX. ENG.   TURB.    ENG.     ENG.                ENG. BHP
 VTIP      RHP        VTIP      RPM       VTIP   FUEL FLOW    AUX       PROP   FUEL FLOW   TEMP.    CODE     PEHF                OR THRUST
 (FPS)                (FPS)               (FPS)   (LBS/HR)                      (LBS/HR)

CPFRC     CPINC      CPF/R     CPNUD       CDO     DELCDS    DELCDM     CXR       J        CP       CT       CLW         CDW          RN


1.347       150.00    1820.2     14823.    1000.       75.6   1375.0       F      74.5    0.176    0.056     -1.5         967.        1093.
725.0         906.     690.0        57.     ----      813.     ----    0.839    155.   1207.7      P       0.044                       55.
0.000150 0.000162 0.000033  0.000009 0.00822   0.0        0.00039 0.000183   ----     ----     ----      0.400        0.007        0.942

1.397       150.00    1868.6     14774.    1000.       75.6   1374.4       P      74.5    0.176    0.056     -1.5         966.        1090.
725.0         903.     690.0        57.     ----      812.     ----    0.839    155.   1207.6      P       0.044                       55.
0.000150 0.000160 0.000033  0.000009 0.00822   0.0        0.00038 0.000183   ----     ----     ----      0.400        0.007        0.942

1.447       150.00    1916.9     14726.    1000.       75.6   1373.8       P      74.5    0.176    0.056     -1.5         965.        1087.
725.0         900.     690.0        57.     ----      811.     ----    0.839    155.   1207.6      P       0.043                       55.
0.000150 0.000159 0.000033  0.000009 0.00822   0.0        0.00038 0.000183   ----     ----     ----      0.400        0.007        0.942

1.497       150.00    1965.2     14678.    1000.       75.6   1373.2       P      74.5    0.176    0.056     -1.5         964.        1083.
725.0         897.     690.0        57.     ----      810.     ----    0.839    155.   1207.6      P       0.043                       55.
0.000150 0.000158 0.000033  0.000009 0.00822   0.0        0.00038 0.000183   ----     ----     ----      0.400        0.007        0.942

1.547       150.00    2013.4     14630.    1000.       75.6   1372.6       P      74.5    0.176    0.055     -1.5         963.        1080.
725.0         894.     690.0        57.     ----      809.     ----    0.839    155.   1207.5      P       0.043                       55.
0.000150 0.000157 0.000033  0.000009 0.00821   0.0        0.00038 0.000183   ----     ----     ----      0.400        0.007        0.942

1.597       150.00    2061.6     14581.    1000.       75.6   1372.0       F      74.5    0.176    0.055     -1.5         962.        1077.
725.0         891.     690.0        57.     ----      808.     ----    0.839    155.   1207.5      P       0.043                       55.
0.000150 0.000156 0.000033  0.000009 0.00821   0.0        0.00038 0.000183   ----     ----     ----      0.400        0.007        0.941

1.647       150.00    2109.7     14533.    1000.       75.6   1371.4       F      74.5    0.176    0.055     -1.5         961.        1074.
725.0         888.     690.0        57.     ----      807.     ----    0.839    155.   1207.4      P       0.043                       55.
0.000150 0.000155 0.000032  0.000009 0.00821   0.0        0.00037 0.000182   ----     ----     ----      0.400        0.007        0.941

1.697       150.00    2157.7     14485.    1000.       75.6   1370.8       P      74.5    0.176    0.055     -1.5         960.        1070.
725.0         885.     690.0        56.     ----      806.     ----    0.839    155.   1207.4      P       0.043                       54.
0.000150 0.000154 0.000032  0.000009 0.00821   0.0        0.00037 0.000182   ----     ----     ----      0.400        0.007        0.941

1.747       150.00    2205.7     14437.    1000.       74.6   1370.5       P      73.5    0.174    0.055     -1.5         959.        1068.
725.0         883.     690.0        56.     ----      805.     ----    0.839    154.   1206.2      P       0.042                       53.
0.000149 0.000155 0.000031  0.000009 0.00818   0.0        0.00035 0.000179   ----     ----     ----      0.400        0.007        0.942

1.797       150.00    2253.7     14389.    1000.       74.6   1369.9       P      73.5    0.174    0.055     -1.5         958.        1065.
725.0         879.     690.0        56.     ----      804.     ----    0.839    154.   1206.2      P       0.042                       53.
0.000149 0.000154 0.000031  0.000009 0.00818   0.0        0.00035 0.000178   ----     ----     ----      0.400        0.007        0.942

1.847       150.00    2301.6     14341.    1000.       74.6   1369.3       P      73.5    0.174    0.054     -1.5         957.        1061.
725.0         876.     690.0        56.     ----      803.     ----    0.839    154.   1206.2      P       0.042                       53.
0.000149 0.000153 0.000031  0.000009 0.00818   0.0        0.00034 0.000178   ----     ----     ----      0.400        0.007        0.942
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      CLIMB  TO  3000.  FT. WITH   MAXIMUM R/C  AT  NORMAL   ENGINE RAT
         ** TAS(AND EAS) IS THE HORIZONTAL COMPONENT OF THE FLIGHT PATH

                                                         PRIM.   .PRIM.               CT PRIME
                    FUEL                  PRES.          TURB.    ENG.                  OVER    ALPHA
TIME      RANGE     USED      WEIGHT      ALT.     TAS   TEMP.    CODE    EAS     MU    SIGMA    D/L     GAMMA    BHP     R/C
(HRS)     (N.M.)    (LBS)     (LBS.)      (FT)    (KTS)  (R)             (KTS)                  (DEG)    (DEG)           (FPM)

                                                                                 AUX.   AUX.    AUX.            AUX.
M.ROTOR   M.ROTOR   T.ROTOR   T.ROTOR     PROP   PRIM.ENG  BHP    ETAP  UX. ENG.  TURB.  ENG.    ENG.         ENG. BHP
 VTIP      RHP       VTIP      RHP        VTIP   FUEL FLOW AUX    FRCP  UEL FLOW  TEMP.  CODE    PERF         OR THRUST
(FPS)               (FPS)                 (FPS)  (LBS/HR)               (LBS/HR)

CPPRO     CPIND     CPPAR     CPMUD       CDO     DELCDS  DELCDM   CXR     J      CP      CT     CLW     CDW      RN


1.847        150.00    2301.6     14341.   1000.     71.5   1856.0      T     70.5   0.169   0.055    -2.6   11.3     1905. 1469.
725.0           943.    650.0        56.   ----      874.   ----    0.820      0.  1856.0     T     0.838               0.
0.000147 0.000159  0.000054  0.000008  0.00813  0.0      0.00030 0.000317  ----   ----    ----    0.400  0.007     0.943

1.853        150.41    2306.6     14336.   1500.     71.5   1856.0      T     69.9   0.169   0.055    -2.6   11.0     1884. 1429.
725.0           943.    650.0        57.   ----      863.   ----    0.820      0.  1856.0     T     0.840               0.
0.000147 0.000164  0.000054  0.000008  0.00815  0.0      0.00033 0.000318  ----   ----    ----    0.400  0.007     0.946

1.859        150.83    2311.6     14331.   2000.     72.5   1856.0      T     70.4   0.171   0.056    -2.6   10.6     1864. 1389.
725.0           945.    650.0        57.   ----      852.   ----    0.820      0.  1856.0     T     0.841               0.
0.000149 0.000166  0.000056  0.000009  0.00820  0.0      0.00038 0.000326  ----   ----    ----    0.400  0.007     0.945

1.865        151.28    2316.7     14326.   2500.     72.5   1856.0      T     69.9   0.171   0.057    -2.6   10.3     1843. 1349.
725.0           946.    650.0        57.   ----      842.   ----    0.820      0.  1856.0     T     0.843               0.
0.000149 0.000171  0.000057  0.000009  0.00823  0.0      0.00041 0.000327  ----   ----    ----    0.400  0.007     0.946

1.871        151.73    2321.9     14321.   3000.     72.5   1856.0      T     69.4   0.171   0.058    -2.5   10.0     1823. 1308.
725.0           947.    650.0        56.   ----      831.   ----    0.820      0.  1856.0     T     0.844               0.
0.000150 0.000177  0.000057  0.000009  0.00826  0.0      0.00044 0.000328  ----   ----    ----    0.400  0.007     0.947
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CRUISE AT SPEED FOR 99 PER CENT BEST RANGE WITH HEADWIND OF    0.0

                                                    PRIM.     PRIM.                        CT PRIME
TIME     RANGE      FUEL                 PRES.                TURB.     ENG.                           OVER      ALPHA        SPEC.
(HRS)    (N.M.)     USED       WEIGHT    ALT.       TAS        TEMP.     CODE      EAS       MU        SIGMA     D/L          RANGE         BHP
                    (LBS)      (LBS.)    (FT)       (KTS)      (R)                 (KTS)                          (DEG)        (NMPP)

                                                                                             AUX.      AUX.      AUX.                       AUX.
M.ROTOR  M.ROTOR    T.ROTOR    T.ROTOR   PROF       PRIM.ENG   BHP       ETAP      UX. ENG.  TURB.     ENG.      ENG.                    ENG. BHP
 VTIP    RHP         VTIP      RHP       VTIP       FUEL FLOW  AUX       PROP      UEL FLOW  TEMP.     CODE      PEFF                    OR THRUST
(FPS)               (FPS)                (FPS)      (LBS/HR)                       (LBS/HR)

CPPRO    CPINC      CPFAR      CPNUO     CDO        DELCDS     DELCDM    CXR       J         CP        CT        CLW          CDW           RN


1.871       151.73    2321.9     14321.   3000.       150.1    1460.1        P     143.6     0.349     0.044      -2.8       .11817         1613.
725.0        1367.     650.0       100.   ----         937.    ----      0.826     335.     1609.1     P         0.547                       672.
0.000361 0.000050  0.000114  0.000041  0.01443     0.00001  0.00652  0.000273    ----      ----     ----       0.500       0.007          0.723

1.971       166.73    2448.9     14194.   3000.       150.1    1458.7        P     143.6     0.349     0.044      -2.8       .11842         1605.
725.0        1360.     650.0       100.   ----         934.    ----      0.826     334.     1608.7     P         0.547                       672.
0.000360 0.000049  0.000114  0.000040  0.01438     0.00001  0.00647  0.000273    ----      ----     ----       0.500       0.007          0.721

2.071       181.73    2575.5     14067.   3000.       150.1    1457.3        P     143.6     0.349     0.043      -2.8       .11867         1597.
725.0        1353.     650.0       100.   ----         932.    ----      0.826     334.     1608.2     P         0.546                       671.
0.000359 0.000048  0.000113  0.000040  0.01434     0.00001  0.00643  0.000273    ----      ----     ----       0.500       0.007          0.718

2.171       196.73    2701.9     13941.   3000.       150.1    1455.9        P     143.6     0.349     0.042      -2.9       .11892         1590.
725.0        1346.     650.0        99.   ----         929.    ----      0.826     334.     1607.7     P         0.546                       670.
0.000357 0.000047  0.000113  0.000039  0.01429     0.00000  0.00639  0.000272    ----      ----     ----       0.500       0.007          0.716

2.271       211.73    2828.1     13815.   3000.       150.1    1454.6        P     143.6     0.349     0.042      -2.9       .11917         1582.
725.0        1339.     650.0        99.   ----         927.    ----      0.826     334.     1607.2     P         0.545                       670.
0.000356 0.000045  0.000113  0.000039  0.01425     0.00000  0.00634  0.000272    ----      ----     ----       0.500       0.007          0.713

2.371       226.73    2953.9     13689.   3000.       150.1    1453.2        P     143.6     0.349     0.041      -2.9       .11941         1575.
725.0        1332.     650.0        99.   ----         925.    ----      0.826     333.     1606.8     P         0.544                       669.
0.000355 0.000044  0.000113  0.000038  0.01420     0.00000  0.00630  0.000272    ----      ----     ----       0.500       0.007          0.711

2.471       241.73    3079.6     13563.   3000.       150.1    1451.9        P     143.6     0.349     0.041      -3.0       .11966         1568.
725.0        1325.     650.0        99.   ----         922.    ----      0.826     333.     1606.3     P         0.544                       668.
0.000354 0.000043  0.000113  0.000038  0.01416     0.00000  0.00626  0.000271    ----      ----     ----       0.500       0.007          0.708

2.571       256.73    3204.9     13438.   3000.       150.1    1450.6        P     143.6     0.349     0.040      -3.0       .11990         1561.
725.0        1318.     650.0        99.   ----         920.    ----      0.826     333.     1605.8     P         0.543                       667.
0.000353 0.000042  0.000113  0.000037  0.01412     0.00000  0.00622  0.000271    ----      ----     ----       0.500       0.007          0.705

2.670       271.73    3330.0     13313.   3000.       150.1    1449.3        P     143.6     0.349     0.040      -3.0       .12015         1553.
725.0        1312.     650.0        98.   ----         918.    ----      0.826     333.     1605.3     P         0.543                       667.
0.000352 0.000041  0.000113  0.000037  0.01408     0.00000  0.00617  0.000271    ----      ----     ----       0.500       0.007          0.703

2.770       286.73    3454.9     13188.   3000.       150.1    1448.0        P     143.6     0.349     0.039      -3.1       .12038         1546.
725.0        1305.     650.0        98.   ----         916.    ----      0.826     332.     1604.9     P         0.542                       666.
0.000351 0.000040  0.000113  0.000036  0.01403     0.00000  0.00613  0.000271    ----      ----     ----       0.500       0.007          0.700

2.859       300.00    3565.1     13078.   3000.       150.1    1446.9        P     143.6     0.349     0.039      -3.1       .12060         1540.
725.0        1299.     650.0        98.   ----         914.    ----      0.826     332.     1604.5     P         0.542                       665.
0.000350 0.000039  0.000112  0.000036  0.01400     0.00000  0.00610  0.000270    ----      ----     ----       0.500       0.007          0.697
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    LOITER  FOR  0.250 HRS. FOR RESERVE FUEL

                                                                 PRIM.     PRIM.                     CT PRIME
                        FUEL                  PRES.              TURB.     ENG.                        OVER      ALPHA      TOTAL
TIME        RANGE       USED       WEIGHT     ALT.      IAS      TEMP.     CODE      EAS       MU      SIGMA     D/L        FUEL FLOW       BHP
(HRS)       (N.M.)      (LBS)      (LBS.)     (FT)      (KTS)    (R)                 (KTS)                       (DEG)      (LBS/HR)

                                                                                               AUX.    AUX.      AUX.
M.ROTOR     M.ROTOR     T.ROTOR    T.ROTOR    PROP     PRIM.ENG  BHP       ETAP    UX. ENG.    TURB.   ENG.      ENG.                      AUX.
 VTIP        RHP         VTIP       RHP       VTIP     FUEL FLOW AUX       PROP    UEL FLOW    TEMP.   CODE      PERF                   ENG. BHP
(FPS)                   (FPS)                 (FPS)    (LBS/HR)                    (LBS/HR)                                             OR THRUST

CPFPO       CPIND       CPPAR      CPNUD      CDO      DELCDS    DELCDM    CXR       J         CP      CT        CLW        CDW             RN


2.659         300.00    3565.1      13078.    3000.       73.1   1361.3      P      69.9     0.170    0.053    -2.2        835.           1022.
725.0           841.     690.0         53.    ----        758.   ----      0.839    78.      852.1    P        0.0                           0.
0.000148  0.000146  0.000045    0.000008  0.00820   0.0        0.00037  0.000264  ----     ----     ----     0.400       0.007          0.943

2.909         300.00    3606.9      13036.    3000.       73.1   1360.8      P      69.9     0.170    0.052    -2.3        835.           1019.
725.0           839.     690.0         53.    ----        757.   ----      0.839    78.      852.1    P        0.0                           0.
0.000148  0.000145  0.000045    0.000008  0.00820   0.0        0.00037  0.000264  ----     ----     ----     0.400       0.007          0.942

2.959         300.00    3648.6      12994.    3000.       73.1   1360.3      P      69.9     0.170    0.052    -2.3        834.           1017.
725.0           836.     690.0         53.    ----        756.   ----      0.839    78.      852.1    P        0.0                           0.
0.000148  0.000144  0.000045    0.000008  0.00820   0.0        0.00036  0.000263  ----     ----     ----     0.400       0.007          0.942

3.009         300.00    3690.3      12953.    3000.       73.1   1359.7      P      69.9     0.170    0.052    -2.3        833.           1014.
725.0           833.     690.0         53.    ----        755.   ----      0.839    78.      852.1    P        0.0                           0.
0.000149  0.000143  0.000045    0.000008  0.00820   0.0        0.00036  0.000263  ----     ----     ----     0.400       0.007          0.942

3.059         300.00    3731.9      12911.    3000.       73.1   1359.2      P      69.9     0.170    0.052    -2.3        832.           1011.
725.0           831.     690.0         53.    ----        755.   ----      0.839    78.      852.1    P        0.0                           0.
0.000148  0.000142  0.000045    0.000008  0.00820   0.0        0.00036  0.000263  ----     ----     ----     0.400       0.007          0.942

3.109         300.00    3773.5      12869.    3000.       72.1   1358.6      P      69.0     0.168    0.052    -2.2        831.           1008.
725.0           828.     690.0         53.    ----        754.   ----      0.839    78.      852.1    P        0.0                           0.
0.000147  0.000144  0.000044    0.000007  0.00817   0.0        0.00034  0.000258  ----     ----     ----     0.400       0.007          0.943

                 MISSION FUEL REQUIRED =  3565.08
                 RESERVE FUEL REQUIRED =   208.46
                 TOTAL   FUEL REQUIRED =  3773.53

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